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PHYTOPATHOLOGY

VOLUME VII NUMBER 5

OCTOBER, 1917

ALTERNARIA ON DATURA AND POTATO

R. D. RANDS

WITH FOUR FIGURES IN THE TEXT

During the progress of studies on the early blight of potato caused by *Alternaria solani* (E. & M.) J. & G., an investigation has been made of the various host relations attributed to this fungus. Throughout the literature the early blight organism is claimed to be the cause of the leaf-spot of Jimson weed (*Datura*, various species). One author (Chester, 1892) goes so far as to state that this was probably the original host, the fungus going from it to the potato and tomato. The object of this paper is to present some comparative studies of early blight and the Datura leaf-spot in order to clear the apparent misunderstanding of the relationship between these two diseases.

The Datura leaf-spot has been under the observation of the author in the University Pharmaceutical Garden, Madison, Wisconsin, during the summers of 1915 and 1916. The spots show a zonation similar to that of early blight but they are straw colored rather than deeply stained (fig. 1). They first appear on the lower more shaded leaves. Under favorable conditions the disease spreads gradually upwards when finally, in late autumn, the seed pods often develop dark sunken lesions (fig. 2). When a leaf becomes weakened by a number of enlarged spots it is usually shed from the plant.

The disease was noted on the following species and varieties growing in the Pharmaceutical Garden September 15, 1915:[1]

Datura tatula Linn., *D. tatula inermis*, *D. stramonium* Linn., *D. stramonium inermis*, *D. stramonium giganteum*, *D. inermis* Jacq., *D. fastuosa* Linn., *D. ferox* Linn., *D. laevis*, *D. quercifolia* H. B. K., *D. leichardtii* F. Muell., *D. metel* Linn.(?).

[1] The species and varieties are listed in the form in which they were found on the garden labels. Since the seed was originally of German origin the names are presumably those in common usage in the foreign seed trade.

The pod blight was especially conspicuous on *D. tatula inermis, stramonium inermis* and *fastuosa*, while the leaf-spot occurred on all to a greater or less extent. *Datura stramonium giganteum* showed greater resistance than the others.

ECONOMIC IMPORTANCE OF THE DISEASE

As is well known, the Daturæ furnish one of the sources of the drug atropin or daturin which is obtained from the leaves. The leaves are picked in late September sufficiently early to avoid frost. It is evident that anything which tends, particularly in the latter part of the season, to reduce the leaf area seriously interferes with its economic use. Estimates made in September 1915, placed the average for all varieties at 40 to 50 per cent of the total leaf surface destroyed. The dry season of 1916 prevented much appearance of the disease prior to the rains of September. But even after that, favorable weather continuing, a loss of 10 to 15 per cent in leaf area occurred.

HISTORY OF THE DISEASE AND ITS CONFUSION WITH EARLY BLIGHT

The first reference inferring that a relationship exists between this disease and early blight is that by Cooke (1883). He describes, as though they were identical, the fungus from Datura and that from the tomato as *Macrosporium solani* Cooke. He was apparently unaware that the same binomial had been applied by Ellis and Martin to a similar fungus on the potato the year before. Saccardo (1886) lists Cooke's fungus as *Macrosporium cookei* Sacc. Later Ellis (see Jones 1893) affirms that this is the same fungus which he and Martin described. Thus the confusion seems to have originated. It is shown by the following references which are apparently concerned with this Datura leaf-spot. Kellerman (1885) from Manhattan, Kansas, Halsted (1893) from New Jersey, Briosi and Cavara (1892) and Ferraris (1913) from Italy, Stevens (1896) from Ohio, Underwood and Earle (1897) and Atkinson (1897) from Alabama, Jones and Grout (1897) and Orton (1899) fom Vermont. So far as the literature reveals the above determinations were based entirely on morphological evidence and on the similarity of the disease to early blight of potato and not on inoculation work with the causal organism.

In order to determine whether the leaf-spot as found at Madison is the same as that reported elsewhere, exsiccatae labelled *Macrosporium solani* E. & M. on Datura, were examined and compared with typical material collected here. The macroscopic appearance of the spots of the exsiccatae of Seymour and Earle (No. 340) and other collections from

FIG. 1. LEAF-SPOT OF DATURA TATULA CAUSED BY ALTERNARIA CRASSA
Photographed September 20, 1915

Florida, Mississippi, Illinois, Kansas, and North Carolina is identical with the Madison material. During the summer of 1916 letters of inquiry and request for fresh material were sent to a number of plant pathologists in different parts of the United States. Specimens received from H. H. Whetzel, Ithaca, New York; B. B. Higgins, Experiment, Georgia; J. A. Elliott, Newark, Delaware; and C. D. Learn, Stillwater, Oklahoma, confirmed the above conclusions concerning the identity and wide distribution of this disease. The material represented only the two common species, *Datura tatula* and *D. stramonium*. Pure cultures from single spores of

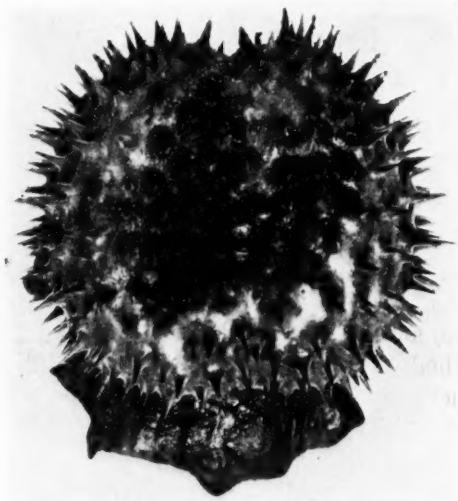

FIG. 2. POD BLIGHT ON DATURA STRAMONIUM VAR. GIGANTEUM, CAUSED BY ALTERNARIA CRASSA

an Alternaria were obtained from each lot which, upon comparison and subsequent pathogenicity tests, proved to be identical and the cause of the disease. Reciprocal cross-inoculations were then made with this fungus and *Alternaria solani* from potato on their respective hosts.

INOCULATION EXPERIMENTS WITH ALTERNARIA SOLANI

In table 1 is shown the results of greenhouse inoculations where *A. solani* isolated from potato was comparatively tested on two of its known hosts and on Jimson weed. Besides the introduction of spores or mycelium into needle pricks, the following methods of inoculation were used: (1) Drop of spore suspension in water on flat portion of leaf inclosed beneath an ordinary round cover slip for twenty-four hours. (2) Leaves

atomized with a spore suspension in water and for forty-eight hours kept moist by a fine spray from a nozzle. In most cases reisolations made from the infected plants were successful.

On September 4, 1916, further inoculations with spores of *Alternaria solani* were made on mature potato and Datura plants growing in the field. Several leaves were atomized with a heavy spore suspension, while with others spores were introduced into punctures. Successful reisolations of the fungus was secured from both atomized and needle punctured leaves on the potato. In one instance tissue plantings from the browned needle punctures on *Datura stramonium* five weeks after inoculation gave the fungus. The results corroborate the green house tests and show that, in no case, was *A. solani* able to form spots on even the old and weakened leaves of Jimson weed. However *in toto* fixations showed that penetration and incipient infection occurred in many cases. But the fungus seemed unable to establish itself and bring about enlargement of the spot.

INOCULATIONS WITH THE FUNGUS FROM DATURA

The Madison culture of the parasite from *Datura stramonium* was tested comparatively first in the greenhouse, and later in the field on Jimson weed, potato, tomato, and on *Solanum nigrum*, the common black nightshade. Several methods of inoculation in which mycelium or spores were placed in needle pricks and the spores atomized upon the surface were used. Most of the tests were carried out at the same time and under the same conditions as those already reported with *Alternaria solani* from potato. These experiments may be briefly summarized as follows: On the Jimson weeds including *Datura stramonium*, *D. inermis*, and *D. tatula*, typical spots 3 to 10 mm. in diameter invariably resulted after two weeks. On potato, tomato and *Solanum nigrum*, incipient infections in the form of tiny brown specks often occurred. They were less abundant on the nightshade and vigorous leaves of tomato. These spots in no case enlarged, even after the leaves were yellowing and dying. The fungus was reisolated readily from the Datura leaves but only in a few cases could it be obtained from the incipient spots on the other plants. The needle punctures on the latter were in most cases entirely healed after eight days. Therefore, it appears that we have here an Alternaria which, though bearing much superficial resemblance to *Alternaria solani*, is nevertheless distinct in its host relationship. In no instance has there been observed any crossing over to the potato or other hosts of *A. solani* tested, and also no crossing of the potato fungus to Jimson weed. The above conclusion is further confirmed by a comparison of the two fungi in other particulars.

TABLE 1

Greenhouse inoculations with Alternaria solani, Madison, Wisconsin, 1916

DATE	INOCULUM	PLANTS INOCULATED, CONDITION, ETC.	METHOD OF INOCULATION	RESULTS
February 19	Mycelium	Potato, 10 in. high; vigorous	5 leaves punctured (mycelium + cover slip)	February 23. Dark spots 2 to 4 mm. diam.
			3 leaves with No. 1	February 23. Specks 1 to 2 mm. diam. March 3. All have well developed dark spots 5 to 15 mm. diam. some sporulation
		Datura stramonium, 4 in. high; very vigorous	As with potato	February 23. No evidence of infection March 3. Two punctures straw colored spots infection doubtful; no results under cover slips
March 20	Spores	Potato, 6 to 8 in. high; very vigorous; 11 inoculations	No. 1	March 22. Black dots beneath most of covers April 10. Spots 1 to 3 mm. diam.
		Datura inermis, 2 plants 6 in. high; vigorous; 20 inoculations	No. 1	March 22. No change April 10. No spots developed
April 13	Spores	Potato, 1 plant 12 in. high; vigorous	No. 2	April 20. Minute spots on every leaf; wet continuously
		Tomato, 1 plant; vigorous	No. 2	April 20. Few spots; not continuously wet
		Datura stramonium, 1 plant; vigorous	No. 2	April 20. No evidence of infection; continuously wet

May 7	Spores	Potato, 1 plant 14 in. high; vigorous	No. 2	May 14. Many spots 1 to 3 mm. diam.
		Tomato, 2 plants 16 in. high; vigorous	No. 2	May 14. Spots abundant on lower leaves
		Datura stramonium, 2 ft. high; vigorous	No. 2	May 14. Many specks on lower leaves but no subsequent enlargement

TABLE 2

Field inoculations with Alternaria solani on potato and Datura

PLANT TESTED	SIZE AND CONDITION OF PLANT	RESULT AFTER TWO WEEKS		RESULT AFTER FIVE WEEKS	
		Atomized leaves	Needle punctured leaves	Atomized leaves	Needle punctured leaves
Potato	Young upper leaves; vigorous	Many spots 3 to 5 mm. diam. coalescing	100% infection; spots 3 to 6 mm. diam.	Leaves dying from abundance of spots	
Datura stramonium	2 to 3 ft. high; weakened by drought and red spider	Peppered with spots 0.5 to 1 mm. diam.	Faint browning of margins of punctures	No change	No change
Datura tatula	2 to 3 ft. high; weakened by drought and red spider	Peppered with spots 0.5 to 1 mm. diam.	Faint browning of margins of punctures	No change	No change
Datura inermis	2 to 5 ft. high; fairly vigorous	Few specks found	Faint browning of margins of punctures	No change	No change

COMPARISON OF THE FUNGUS FROM DATURA WITH ALTERNARIA SOLANI

On hard potato agar the colony of Alternaria from Datura is at first of a light olivacious color with faint pinkish margins; later the entire growth becomes a grayish white while from the lower surface often blackish mycelium can be seen through the agar. With *A. solani* the grayish or brownish colony produces a deep pinkish to yellowish pigmentation of the agar which often extends in advance of the mycelium (fig. 3). This furnishes at once a distinct physiological basis for the differentiation of the two fungi. Morphologically they are similar in many respects. One of the most prominent characters which distinguishes the Datura fungus from *A. solani* is found in the terminal prolongation or beak of the spore. In the former the beak is coarser, more elongated, rarely has any pronounced tapering to the tip, and is never forked or divided (fig. 4). Often as high as 75 per cent of the spores of *A. solani* both from cultures and from spots, have been observed to possess forked or variously divided beaks, the subdivisions tapering more or less to the tip. One hundred spores from typical early blight spots from potato gave a range in size of 120 to 296 by 12 to 20 μ and an average of 200 by 17 μ. With the Datura fungus the range in size was 128 to 448 by 16 to 40 μ with an average of 261 by 23 μ. The latter it is seen has spores considerably larger in both dimensions than *A. solani*. However, the difference is not such as to make spore measurements reliable when not supplemented by the other distinguishing characters mentioned.

IDENTITY OF THE DATURA PARASITE

The fungus has been referred to as an Alternaria. This was, however, merely on account of its great similarity to *Alternaria solani*. As in the case of the latter, cultures, on oatmeal agar occasionally develop spores in catenulate pairs (fig. 4). According to the present delimitations of the genera Alternaria and Macrosporium this catenulation of spores makes the fungus an Alternaria. However, it is realized that the conditions under which spore pairs are formed are possibly abnormal and it is doubtful if the fungus behaves similarly under natural conditions on its host. At any rate the examination of many spots has failed to reveal it. Thus the taxonomic position of the fungus is problematical. Until these two genera are more clearly defined it will be called provisionally an Alternaria.

To what species the fungus should be referred was a matter of doubt for some time. A careful search of the literature failed to reveal a description of a species of Alternaria on Datura. One Macrosporium, *M. daturæ* Faut. (Lambotte and Fautrey 1894), is described as occurring on

Datura stramonium on the sterile spots of an undetermined species of Sphaeropsidales

The spore measurements (150 to 190 by 18 to 20 μ) fall within those given in this paper and the long slender "pedicel" (referring to the terminal beak) also is characteristic of the fungus under consideration. While it is probable that the two may be identical the description is entirely too brief for one to be certain. The question was referred to Dr. J. J. Davis. After looking over the various fungi described for Datura, he expressed the belief that this Alternaria (or Macrosporium), in an immature condition, was probably the same which Saccardo (1877 *b*) describes under

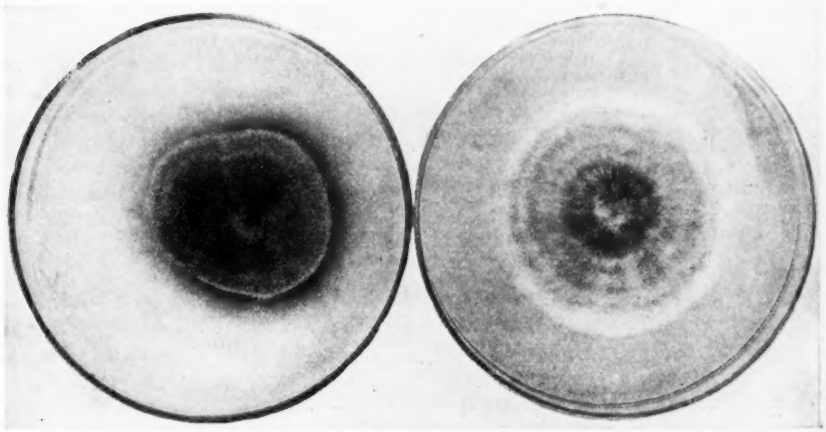

FIG. 3. SEVEN-DAYS-OLD CULTURES OF ALTERNARIA SOLANI (LEFT) AND ALTERNARIA CRASSA (RIGHT)

The colony in the former is light brownish and produces a pinkish discoloration of the agar (hard potato) often extending in advance of the mycelium; the colony of the latter is grayish white and there is no discoloration of the medium.

the name *Cercospora crassa* Sacc. sp. n. He also found that later Peck (1882) describes under the name *Cercospora daturæ* n. sp. from New York State what seems to be the same. The fungus corresponds with Peck's description in all essentials except that the spore measurements (50 to 75 by 12 μ) fall considerably short. The type specimens collected by Peck have been examined and the appearance of the spot leaves little doubt of their identity with the Madison material. From Saccardo's original illustration (1877 a) and the description in Michelia where the spore measurements are given as 100 to 150 by 15 to 18 μ, there is every evidence that he was dealing with immature material of this same fungus. In

order to relieve all doubt, however, a type specimen distributed in Mycotheca Italica No. 996 Padova, August 1901 was examined.[2]

This well-preserved specimen of a spotted leaf of *Datura stramonium* collected by Saccardo was similar in almost every respect to specimens from Madison and from various other parts of this country. Though the spots are small, their characteristic appearance leaves no doubt of the identity of the two diseases. Furthermore, some spores were obtained from the specimen and they add still further confirmation. As the pres-

FIG. 4. COMPARISON OF SPORE CHARACTERS OF ALTERNARIA CRASSA AND ALTERNARIA SOLANI

In the group of A. crassa (to the left) the first two are typical spores from leaf-spot on Datura stramonium; the third represents a case of catenulation on acidulated potato agar. To the right, typical spores of A. solani showing variation in size and form; these are uniformly smaller than A. crassa and frequently have the beaks branched. × 200.

ence of longitudinal septa in long pointed single spores of Alternaria or Macrosporium is the important character which separates them from Cercospora, it may be readily understood how immature spores of the former might be mistaken for the latter. And Saccardo observed a longitudinal septum, as is shown by his illustration, but he calls it a false one, "septulo spurio." Since it is true that the longitudinal partitions in Alternaria are generally absent until the spores attain full size, it seems probable, as Dr. Davis suggests, that Saccardo's conception was obtained from immature material.

[2] The writer is indebted to Dr. A. B. Stout of the New York Botanical Garden for assistance in making this examination.

Cercospora crassa is listed by Tassi (1906) at the University of Senna, Italy, and also by Ferraris (1910 who gives as its distribution northern Italy, Switzerland, and Germany. The latter describes in addition the following which he considers forms of *Cercospora crassa:* (1) *lunariæ*, on *Lunaria biennis;* (2) *ibiridis*, on *Iberis umbellata;* (3) *solani-nigri*, on *Solanum nigrum.*

These are recorded from Italy alone. The inoculations already described show that *Solanum nigrum* cannot act as a host for this fungus, thus throwing some doubt on the validity of the form reported for this plant. No tests were made on the other plants.

In order to avoid future confusion the probable synonomy of the fungus and a description of the new combination are here given:

Alternaria crassa (Sacc.) n. comb.[3]

Cercospora crassa Sacc. Michelia **1**: 88. 1877.
Cercospora daturæ Peck. Rept. New York State Museum **35**: 140. 1882.
Macrosporium solani Cooke (in part). Grevillea **12**: 32. 1883.
Macrosporium daturæ Fautrey. Rev. Myc. **16**: 76. 1894.
Alternaria solani (E. & M.) Jones & Grout (in part). Bul. Torr. Bot. Club, **24**: 257. 1897.

Conidiophores light brown, erect or ascending, somewhat irregular, septate, generally 2 to 3 cespitose, 70 to 90 by 9 to 10 μ; conidia light brown, obclavate, with very long, septate, filiform, terminal beak, generally much exceeding in length the body of the spore, total dimensions 128 to 448 by 16 to 40 μ, average 261 by 23 μ; body of spore 56 to 140 μ in length, 7 to 9 transverse septa, 1 to 3 longitudinal septa in mature spores (sometimes absent); colony, in potato agar culture, light grayish, cottony, no pigmentation of the medium.

Destructive, causing a leaf-spot and pod blight of Jimson weed (*Datura*, various species).

UNIVERSITY OF WISCONSIN
MADISON, WISCONSIN

[3] Inasmuch as the fungus in nature produces spores singly, and catenulate spores have been observed only in culture, some authors may prefer the combination *Macrosporium crassa.*

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SUSCEPTIBILITY OF NON-CITRUS PLANTS TO BACTERIUM CITRI

R. A. Jehle

With Three Figures in the Text

Various non-citrus plants have been inoculated with pure tested cultures of *Bacterium Citri* Hasse in order to determine their susceptibility to the citrus canker disease. Special attention has been given to related species belonging to the Rue family (Rutaceae). The plants are growing directly in the soil in a securely screened inclosure. No results have been obtained from any of these experiments excepting in the case of *Murraya exotica* (Orange Jessamine) and *Zanthoxylum fagara* (L.) Sarg. (Wild-lime).

In the case of *Murraya exotica* a few watery swellings developed around some of the needle-prick inoculations in the leaves and the canker organism was recovered from the interior of one of the swellings a few weeks later. Inoculations were also made by spraying the twigs and leaves with a suspension of canker bacteria, but the results of these latter tests were negative.

Many inoculations were made on the twigs of all sizes and on the leaves of *Zanthoxylum fagara*. On the leaves watery swellings sometimes surrounded by a yellow halo developed around most of the needle-pricks into which canker bacteria were introduced (fig. 2, *A*). These swellings never burst open, but *Bacterium Citri* was recovered from the interior three months after inoculation. On the twigs a total of about one hundred needle-prick inoculations were made. In every case watery swellings developed in about ten days. These swellings on the twigs continued to increase in size and finally longitudinal splitting of the bark took place exposing a mass of corky cells much resembling canker infections on the twigs of *Citrus trifoliata* (figs. 1 and 3). *Bacterium Citri* was repeatedly recovered from these swellings, which produced typical canker on grapefruit seedlings (fig. 3, *D* and *E*). On *Zanthoxylum fagara* twigs the same organisms produced infections identical with those from which they were isolated. Check inoculations were made by pricking the tissues with a sterilized needle, but the wounds soon healed over (fig. 1, *C*).

Twigs of *Zanthoxylum fagara* were inoculated by spraying a suspension of *B. Citri* in distilled water on the uninjured surface with an atomizer. These twigs were covered for several days with a lamp-chimney plugged

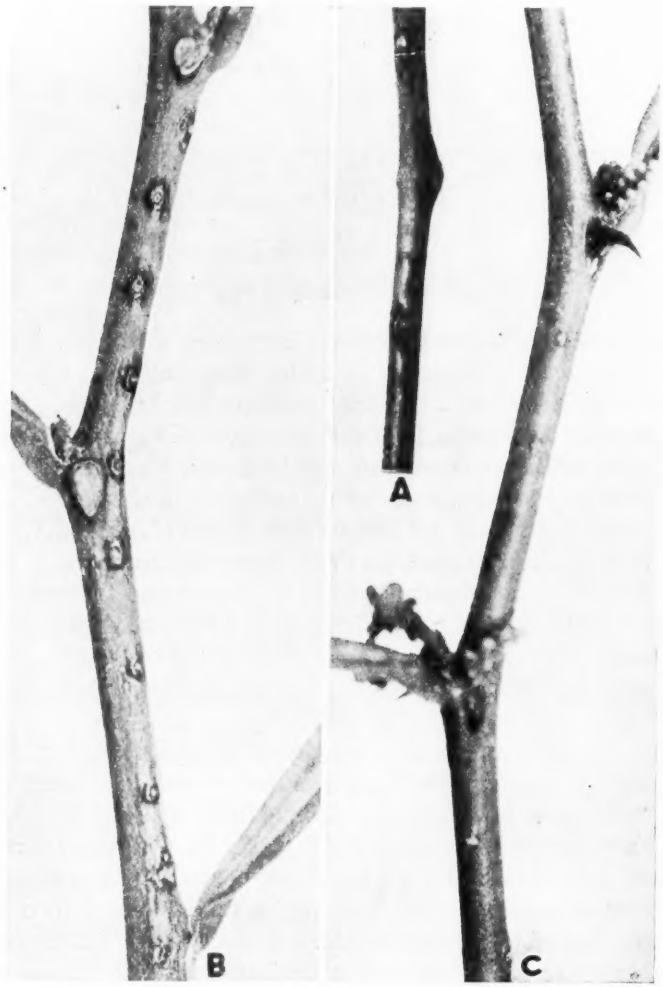

FIG. 1. RESULT OF NEEDLE-PRICK INOCULATIONS WITH BACTERIUM CITRI IN TWIGS OF ZANTHOXYLUM FAGARA

A. Two infections on a young twig of *Zanthoxylum fagara* produced by introducing *Bacterium Citri* into the tissues with a sterilized needle. × 3. The lower lesion almost encircles the twig. Inoculated November 20, 1916. Photograph made February 22, 1917.

B. Ten infections on a twig of *Zanthoxylum fagara* produced by introducing *Bacterium Citri* into the tissues with a sterilized needle. × 3. Inoculated November 20, 1916. Photograph made January 27, 1917.

C. Needle-pricks in a twig of *Zanthoxylum fagara* into which no organisms were introduced. × 3. Pricks made November 20, 1916. Photographed January 27, 1917.

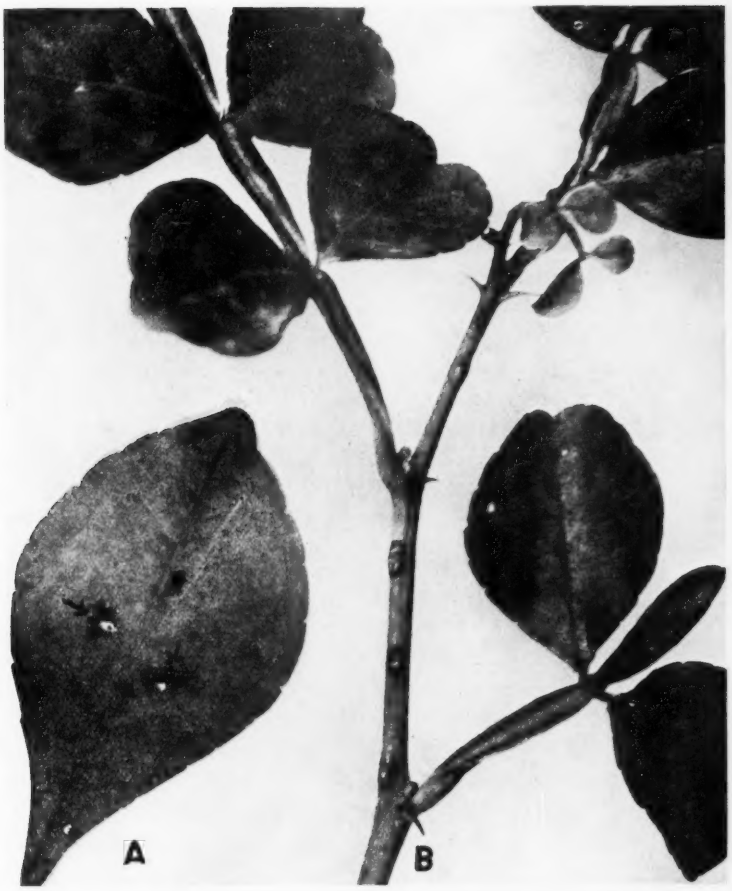

FIG. 2. LESIONS FROM NEEDLE-PRICK INOCULATIONS ON LEAFLET AND TWIG OF ZANTHOXYLUM FAGARA

A. Two lesions on a leaflet of *Zanthoxylum fagara* produced by introducing *Bacterium Citri* into the tissues with a sterilized needle. × 3. Inoculated May 21, 1917. Photographed July 17, 1917.

B. Five infections on a very young twig of *Zanthoxylum fagara* produced by introducing *Bacterium Citri* into the tissues with a sterilized needle. × 3. Inoculated May 21, 1917. Photograph made July 17, 1917.

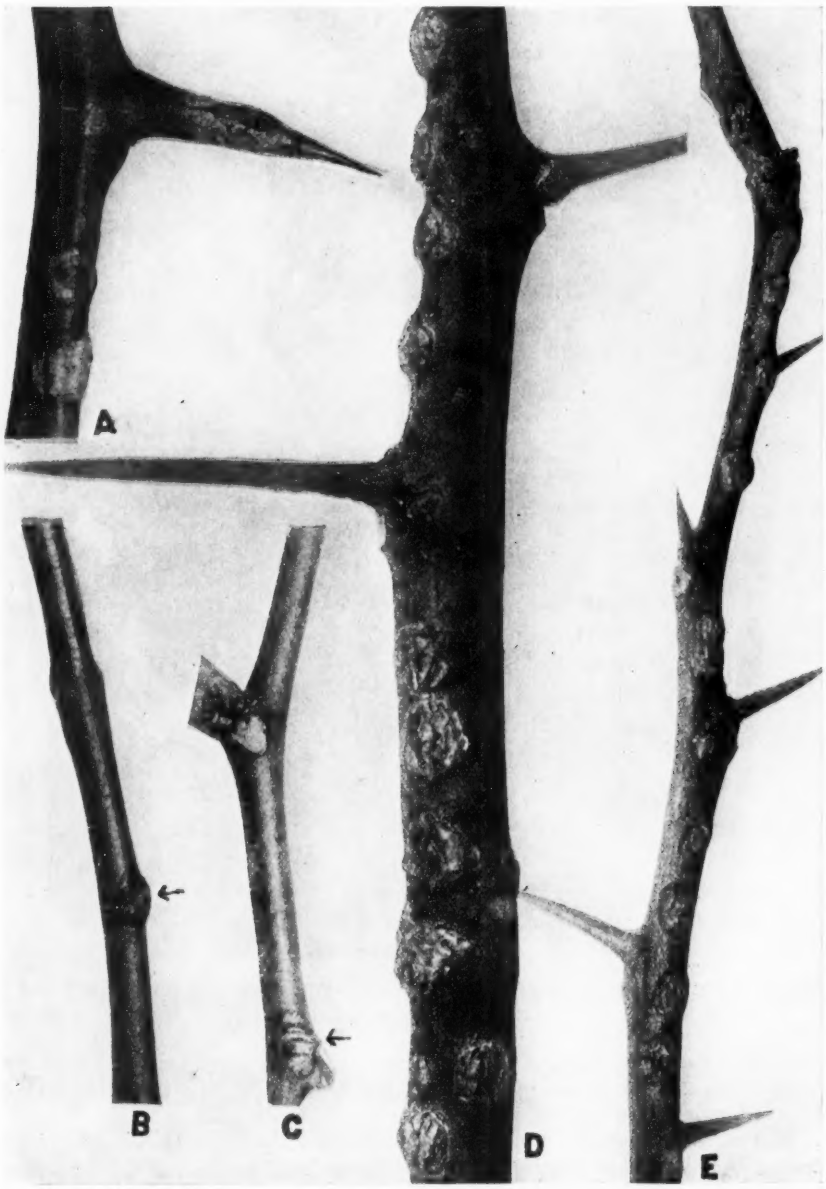

FIG. 3

with cotton at the ends. Other twigs were treated in exactly the same manner excepting that sterilized water containing no *B. Citri* was used in the atomizer. No swellings developed on the twigs sprayed only with sterilized water but five cankers developed on the twigs sprayed with *B. Citri*. The five cankers which developed as a result of the atomizer inoculations were almost identical in appearance. They very much resembled young citrus canker infections on the twigs of *Citrus trifoliata*, but differed from the latter in having a distinct transverse split across the center. In one instance the development of one of these cankers was observed for several months. When the infection was found it was a small dark green watery swelling with a small transverse split in the bark across the center. The swelling continued to increase in size, and the transverse split in the bark became more conspicuous. When the canker had reached about three millimeters in diameter, longitudinal splits began to appear in the bark at the outer ends of the transverse split. The cracks exposed a corky mass of cankerous tissue similar to that on other hosts. The largest canker reached a diameter of five millimeters seven months after inoculation. It was surrounded by an oily zone, indicating that the bacteria were still alive and active in the interior. One of the smallest cankers was removed from the tree (fig. 3, *C*) and isolations were made from the interior. The bacteria recovered from this canker did not differ from other strains of *Bacterium Citri*. They produced typical citrus canker on grapefruit seedlings and infections on *Zanthoxylum fagara* identical with infections produced by other cultures of *Bacterium Citri*.

A grapefruit seedling badly infected with citrus canker was set so that its branches interlocked with those of *Zanthoxylum fagara*. Infections identical with those resulting from inoculations with *B. Citri* have developed on uninoculated twigs and leaves of *Zanthoxylum fagara* near to the infections on the grapefruit seedling. These infections undoubtedly resulted from *B. Citri* washed by rains from the infected grapefruit tree to the twigs and leaves of *Zanthoxylum fagara*.

FIG. 3. RESULT OF INOCULATIONS WITH BACTERIUM CITRI ON THREE DIFFERENT HOSTS

A. Result of an atomizer inoculation with *Bacterium Citri* on a twig and thorn of *Citrus trifoliata*. × 3.

B and *C*. Result of atomizer inoculations on twigs of *Zanthoxylum fagara*. × 3. Both twigs inoculated November 17, 1916.

B, photographed July 18, 1917; *C*, photographed February 14, 1917. Isolations were made from *C* on February 15, 1917 and pure cultures of *Bacterium Citri* were recovered.

D and *E*. Result of needle-prick inoculations on twigs of grapefruit with organisms recovered from interior of canker on a twig of *Zanthoxylum fagara*. × 3.

Although lesions have been occasionally noted on the twigs of *Zanthoxylum fagara* in Dade County hammocks, they have been carefully examined and no evidence has been secured indicating an abundance of natural infestations of this plant with the bacteria of citrus canker.

FLORIDA STATE PLANT BOARD
REDLAND TROPICAL LABORATORY

SOME DISEASES OF ECONOMIC PLANTS IN PORTO RICO

L. E. Miles

With Three Figures in the Text

ISARIOPSIS ON THE BEAN

The Isariopsis leaf-spot of the cultivated bean is a disease which occurs on both the foliage and pods of the bean plant, often resulting in considerable damage to the crop, due to the lessening of the active leaf surface or sometimes to the partial or complete premature defoliation. The disease has not been considered of any great significance commercially, but according to Halstead[1] it is much more common in the United States than is usually supposed, and to it should probably be ascribed much of the trouble formerly attributed to other fungi. It is easily confounded with the leaf-blotch of the bean (Cercospora). The chief points of difference between these two diseases will be considered later in this paper.

The fungus causing the disease, *Isariopsis griseola*, was first described by Saccardo in 1877, as occurring in northern Italy and southern Austria. Briosi and Cavara also report it as occurring in Italy, and it is represented in their exsiccati by a specimen collected near Pavia in 1888. In the exsiccati of Rabenhorst, Winter and Pazschke a specimen is found collected near Zurich in Helvetia. Rabenhorst reports the disease as occurring also in Belgium, Poland and Argentina. It is represented in the collection of North American Fungi of Ellis and Everhart by a specimen collected by J. B. Ellis at Newfield, New Jersey in 1889. In the Fungi Columbiani of Ellis and Everhart, as continued by E. Bartholomew, a specimen is found collected by C. L. Shear at Takoma Park, Maryland, in 1906. Halstead of New Jersey in 1901 reported it as occurring in that state. F. L. Stevens of the University of Illinois found it in abundance on beans in the garden of the Experiment Station of Porto Rico in 1912 and 1913. It is also represented in the collection of J. A. Stevenson by a specimen collected at Rio Piedras, Porto Rico, in 1916. The writer has examined specimens collected by J. L. Sheldon at the following places in West Virginia: Morgantown, 1904; Martinsburg, 1905; Sink's Grove and Bull Run in 1906. The Plant Disease Survey of the United States Department of Agriculture reports it as having been noted in Monroe and

[1] Halstead, B. D. New Jersey Agr. Exp. Sta. Bul. 151. 1901.

Jackson counties of the same state in 1906. Specimens on pods were also collected in Preston Country, Connecticut in this same year by G. P. Clinton. In 1908 it was reported as having caused considerable damage to pole beans and some injury to bush beans at Central Village and Voluntown, Connecticut. In this case the pole beans were killed half way up the poles. The writer has also examined specimens collected by G. P. Clinton at Westville, Connecticut in the years 1902 and 1905. During the summer of 1916 M. F. Barrus found it occurring on beans in the market at Washington, D. C., and the writer has looked over some material which he collected that same year at Chevy Chase, Maryland. Recently also the writer examined some material collected near Managua, Nicaragua, in Central America, by Mrs. G. V. Long, who, not being acquainted with the disease, gathered spotted leaves of the bean at random. Since all the leaves gathered showed this disease, it is probable that it occurs in that locality in considerable abundance.

In spite of this general world distribution, the literature concerning the fungus is meagre. With the exception of Halstead's previously mentioned note of its occurrence and a similar one by Clinton[2] all of the published references to it are brief descriptions of the specimens in exsiccati with the date and place of collection. Furthermore the figures and descriptions are not in accord. Saccardo[3] speaks of the hyphae which contitute the coremium on which the spores are borne as having reflexed tips and his figure[4] represents this character as being very pronounced. Briosi and Cavara[5] have the only other figure that the writer has been able to find with the exception of a copy of Saccardo's in Comes' textbook. This figure does not represent the tips as being at all reflexed and examination of the specimen of Briosi and Cavara shows agreement with their figure in this respect. In all the material that the writer has examined including the greater part of that mentioned previously in this paper no reflexed hyphae have been found.

The Isariopsis leaf-spot is different from the other diseases of the bean in that it is confined more exclusively to the foliage, though in one or two instances it has been reported as occurring on the pods also. On the under side of the leaf are produced numerous small angular spots without a colored border of any sort (fig. 1). It is this angularity of the spots and absence of a colored border that differentiates it so readily from the leaf-blotch of the bean caused by *Cercospora cruenta*. In this latter disease,

[2] Clinton, G. P., Connecticut Agr. Exp. Sta. Rept. **1903**: 308.

[3] Saccardo, P. A. Sylloge Fungorum **4**: 630. 1878.

[4] Saccardo, P. A. Fungi Italici, *fig.* 837. 1878.

[5] Briosi and Cavara, Funghi Parassiti delle Piante Cultivate ed Utili. Fasc. 1, No. 17. Pavia, 1888.

the spots are less angular and are surrounded by a pronounced red-brown border. The middle portions of the spots are also likely to fall out in the older specimens, producing a shot-hole effect. The angularity of the Isariopsis spots is due to the fact that they are bounded and limited by the small veinlets of the leaf. In youth these spots are covered by a gray, moldy coating due to the large number of spores produced but as the spot ages it becomes a pronounced light brown. On close observation it will be seen to be studded with small dots, the coremia, on which the spores are borne in large numbers.

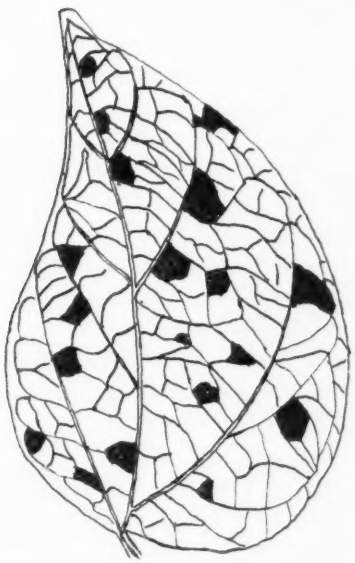

FIG. 1. LEAF OF BEAN SHOWING ANGULAR ISARIOPSIS SPOT

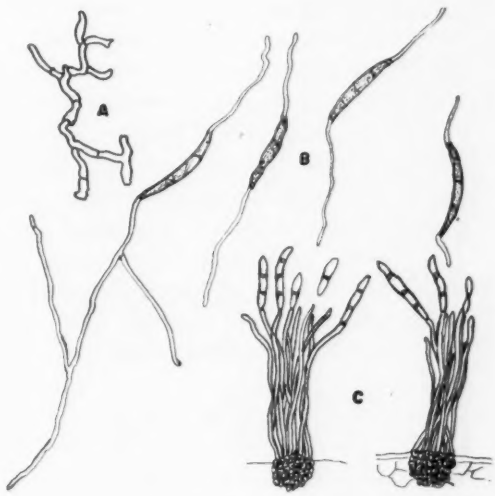

FIG. 2. ISARIOPSIS GRISEOLA
A, mycelium; *B*, germinating spores; *C*, Coremia

The coremia are columnar and are formed of rather dark brownish hyphae closely aggregated, though seemingly not at all united with each other (fig. 2, *C*). The members of the fruiting column tend to separate, especially with age, thus indicating that the structure should perhaps not be regarded as a typical coremium at all. The number of hyphae in a column varies considerably. In some as few as eight hyphae were observed while in others the number often reached thirty or forty. The hyphae are continuous, brownish, becoming paler toward the tip and average about 200 μ in length. The average thickness of the coremium is from 20 to 40 μ.

The conidia are borne on the smooth tips of the hyphae which constitute the coremium (fig. 2, *C*). These tips commonly spread at the top, especially in the older specimens, giving a capitate appearance to the spore cluster. The writer was unable, however, to observe the reflexed tips as described and pictured by Saccardo. The conidia are light gray in color, cylindrical to spindleform, slightly curved, and scarcely, if at all, constricted. They measure 50 to 60 μ in length by 7 to 8 μ in thickness, and are 1- to 3-septate. In a few cases they become 4-septate. The mycelium, though composed of crooked and branching cells, is of practically uniform diameter throughout (fig. 2, *A*). It lives in the leaf tissues and forms dark stromata in the cavities beneath the stomata and from these the coremia arise.

On germination the end cells only, of the 3- or 4-septate spores, send forth mycelial hyphae. These young hyphae are non-septate in the earlier stages and in a short time begin to branch as shown in figure 2, *B*.

No experimental work has yet been done with reference to treatment of the disease, probably because it has not been considered of sufficient economic importance. However, Halstead suggests that, owing to the superficial character of the fungus, the same treatment ordinarily applied to the leaf-blotch or the rust of the bean would probably be effective.

Specimens examined: Rabenhorst, Fungi Eur. 3998; Kunze, Fungi Sel. 595; Briosi and Cavara, Funghi Parassiti, No. 17; Saccardo, P. A., Fungi Ital., Fig. 837; Thümen, Herb. Myc. Sec. 654; Ellis and Everhart, Fungi Columbiani, 2434; Ellis and Everhart, North American Fungi, 2487.

Other specimens collected by: Sheldon, J. F., Morgantown, W. Va., 1186; Martinsburg, W. Va., 1989; Bull. Run, W. Va., 2696; Sink's Grove, W. Va., 2719; Barrus, M. F., Chevy Chase, Md., 9057; Clinton, G. P., Westville, Conn., two packets; Long, Mrs. G. V., Managua, Nicaragua; Stevenson, J. A., Rio Piedras, Porto Rico, 6198; Stevens, F. L., Porto Rican Fungi, Jayuya, 7108; Managuez, 5989; Dos Bocas, 7382; 7952.

CERCOSPORA NICOTIANAE E. & E. ON TOBACCO

Tobacco is third in rank among the exports of Porto Rico, though only a small portion of the area of the island is devoted to its culture. The Cercospora disease may result in great damage to the standing tobacco, and in some instances the crop may be practically ruined. It is most abundant on the lower leaves, appearing as brown, circular spots, from the size of a pin-head to a centimeter or more in diameter, thickly scattered over the entire leaf surface. The older spots are bordered by a dark, raised line, and the centers dry up and become white, often falling

away and leaving irregular holes. The leaf does not decay as a result of the spotting, but turns yellow from the tip downward and ripens prematurely.

Dos Bocas, 7980; Ste. Ana. 7612; Quebradillos, 7270; Caguas, 469; Cailes, 23.

CERCOSPORA HENNINGSII ALESCH. ON CASSAVA

Cassava, *Manihot utillisma*, is cultivated for its thick, fleshy root-stocks, which are densely stored with starch. Although it is not used in Porto Rico nearly as much as it is in some other tropical countries, it is cultivated by the natives to some extent for use as bread and for the starch which it contains. *Cercospora henningsii* causes a small dried-out spot on the leaves, but it is of but little importance, as it probably injures the host but little.

Hormigueso, 233; Santurce, 254.

CERCOSPORA HIBISCI TRACY & EARLE, ON OKRA

Okra is cultivated for its large fruit capsules which are used for food. *Cercospora hibisci* occurs on the lower side of the leaves, not in spots, but as an almost continuous coating. It causes the leaves to turn yellow and fall, weakens the plant and reduces the quantity of pods.

Quebradillas, 5030; Aguadilla, 5229; Cario Raja, 6465.

CERCOSPORA CANESCENS ELL. & MART. ON THE BEAN

Cercospora canescens does some damage to the bean crop, due to small spots on the upper leaf surface, but, as a rule, it does not prove serious.

Guayanilla, 5872.

CERCOSPORA COFFEÆ ZIMM. ON COFFEE

Coffee is by far the most important product of Porto Rico. *Cercospora Coffeæ* causes the appearance on the leaf of spots and the leaves fall, thus reducing the vitality of the plant and preventing the proper maturing of the berries. These spots, as a rule, are round or oval in form, clear brown on the lower side of the leaf, dark brown on the upper side. By uniting, they frequently cause large blotches which dry out and become gray in color at the center. Badly infected leaves appear more or less brown.

Añasco, 3211; Maricao, 4827.

PUCCINIOPSIS CARICÆ EARLE, ON THE PAPAW

The tropical papaw (*Carica papaya*) is attacked by a leaf-spot fungus, *Puccinopsis Caricæ*, which occurs as small, erumpent, black masses on the under side of the leaf, and causes more or less yellowing of the surround-

ing tissue. The attacked leaves die and fall prematurely. The disease is not destructive, but is sometimes reported to be severe on young seedlings. Associated with the causal fungus in all specimens examined by the author was found a very peculiar fungus, *Zygosporium oschioides* Mont., which is represented in figure 3. It occurs as a saprophyte on the Pucciniopsis spots, and is mentioned here only on account of its very interesting peculiarities which are shown in the figure.

Guanica, 348; Vega Baja, 1913; Mona Island, 6334; 6432.

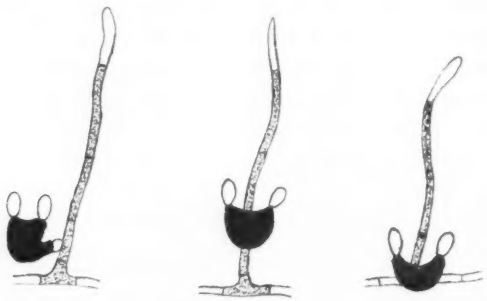

FIG. 3. PUCCINIOPSIS CARICÆ

PHYLLACHORA GRATISSIMA REHM, ON THE AVOCADO

This fungus causes jet-black, erumpent pustules to appear on the upper side of the leaves of the avocado (*Persea americana* Mill.). The spots are from one to two millimeters in diameter, but by coalescing they may become considerably larger. The injury to the plant is probably not very great.

Jayuya, 5974; 6072.

MYCOSPHÆRELLA PERSEÆ MILES (IN ED.) ON THE AVOCADO

This fungus causes very large, irregular spots on the leaves of the avocado. On the upper side of the leaf the spots are covered by a cinereous, papery membrane, and are without a limiting border. On the lower side they are brown, with a narrow border darker brown in color. A single spot may often cover several square centimeters of the leaf surface. The disease is not of any great importance, though it may lessen the vitality of the host somewhat. The description of the fungus may be found in the Proceedings of the Illinois Academy of Science for 1917.

Maricao, 753; 4809; 4486 (type); Rio Piedras, 2176; 2501; San German, 5797; Dos Bocas, below Utuado, 6601.

CERCOSPORA CARBONACEA MILES (IN ED.) ON THE YAM

This fungus causes very conspicuous, black spots, burned or charred in appearance, on the upper side of the leaves. The spots are usually angular in form, limited by the veins or veinlets, and are from one to one and one-half centimeters in diameter. From the number of collections made in Porto Rico, it would appear to be common there, and it cannot be other than injurious to the plant, since it renders so much of the leaf surface inactive. The description of the fungus may be found in the Proceedings of the Illinois Academy of Science for 1917.

Vega Alta, 4178 (type); Cabo Rajo, 6469; Vega Baja, 4234; Anasco, 3563; St. Ana, 6687.

HELMINTHOSPORIUM MAYAGUEZENSE MILES (IN ED.) ON PASPALUM

Paspalum conjugatum Bregius, a forage grass of some commercial importance in Porto Rico, is attacked by a leaf-spot fungus, *Helminthosporium mayaguezense*. The spots occur both on the blades and culms and are quite conspicuous. They are of uniform light yellow color, surrounded by a narrow, dark brown border, regular in outline, oval, and vary from small to a centimeter in length, being usually about one-half as wide as long. In the somewhat paler centers of the spots the unusually large conidiophores of the causal fungus are plainly evident to the unaided eye as small, dark, hair-like bodies. The spots may be so numerous as to practically cover the leaf and must of necessity be of material injury to the general vigor of the host. The description of the fungus may be found in the Proceedings of the Illinois Academy of Science for 1917.

Mayaguez, 970; 1066; 7142 (type); 8232; 8279; 8941; Dos Bocas, 1093; San German, 5803; Anasco, 4904; Maricao, 8776.

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

TWO NEW FOREST TREE RUSTS FROM THE NORTHWEST

H. S. Jackson

CHRYSOMYXA

A large collection of rusts made by Dr. J. R. Weir in various sections of the Northwest, was, through the kindness of Dr. J. C. Arthur, to whom the material was sent in the fall of 1915, referred to the writer for study. Among the material were specimens of a curious rust occurring on the leaves of *Picea Engelmanii* collected in Idaho. Carefully made sections of this form showed that the rust belonged to the genus Chrysomyxa. Examination of undetermined material on the same host in the Arthur herbarium at the Purdue Experiment Station led to the discovery of another specimen of the same rust collected in 1911 in British Columbia by Prof. E. W. D. Holway. Recently Dr. Weir has sent to the writer a third collection made in Oregon in 1916. Since no similar rust has apparently been recorded for America the results of the study of these specimens are considered worthy of record.

The genus Chrysomyxa was established by Unger[1] in 1840 with *C. Abietis* (Wallr.) Ung. as the type species. This is an autoecious leptoform as shown by Reess,[2] telia only, unaccompanied by pycnia being known in the life cycle. This genus has generally been interpreted as including both short and long cycle forms. The Sydows[3] describe sixteen species. Fourteen of these are long cycle forms all of which are known to be, or are assumed to be heteroecious and occur on various members of the Pyrolaceæ, Ericaceæ or Vacciniaceæ with pycnia and aecia so far as determined on Picea. Two short cycled forms *C. Abietis* and *C. Piceæ* Barcl. are included. The former occurs on the leaves of various species of Picea throughout continental Europe; the latter is known only from India on *P. Morinda* and is referred doubtfully to this genus.

Arthur[4] restricted the genus Chrysomyxa to include only the short cycle autoecious forms and established Melampsoropsis (Schröt) for those species having all spore forms. He has recognized[5] eight species of the

[1] Beiträge zur Vergleichenden Pathologie, p. 24. 1840.
[2] Bot. Zeit. **23**: 388. 1865; Abh. Naturf. Gesellsch. Halle **11**: 32. 1869.
[3] Monog. Ured. **3**: 502–520. 1915.
[4] Result. Sci. Congr. Bot. Vienne 338. 1906.
[5] N. Am. Flora **7**: 118–121. 1907.

latter genus in America, four of which have been definitely connected through cultures by European or American investigators with their aecial stages. No American representative of the genus Chrysomyxa has been previously recognized.

A careful study of the collections on *Picea Engelmanii*, referred to in the introductory paragraph has led to the conclusion that they represent an undescribed species, a diagnosis of which follows:

Chrysomyxa Weirii sp. nov.

O. Pycnia unknown, probably not formed.

III. Telia foliicolous on yellowish spots, prominent, waxy in consistency, elongate-elliptical, 0.5 to 1.5 mm. long, occasionally confluent, dull orange to orange-brown, ruptured epidermis conspicuous; teliospores catenulate soon separating, oblong or fusiform, 5 to 7 by 16 to 28 μ, truncate or attentuate at either end, abutted or overlapping, sometimes only slightly so at one side; wall colorless, thin 1 μ or less, smooth.

ON PINACEÆ:

Picea Engelmanii Parry. Gold River British Columbia, June 10, 1911, E. W. D. Holway; Priest River, Idaho, May 1915, J. R. Weir *68;* Whitman National Forest, Oregon, July 17, 1913. J. R. Weir *271*, type.

This species differs from *C. Abietis* in the narrower, somewhat smaller spores which do not long remain in chains but soon break apart. No evidence of germination has been seen in any of the collections. The writer takes pleasure in dedicating the species to Dr. Weir who collected the type specimen and whose work has contributed much to a better understanding of Northwestern Uredineæ.

MELAMPSORA

Two species of Melampsora on Populus have been recorded from the Northwest. One of these *M. albertensis* Arth. is apparently confined to *P. tremuloides*. The other, known on various species of Populus, has generally been referred to *M. Medusæ* Thüm. While working over a large collection of rusts from the herbarium of the Montana Agricultural College in the fall of 1915 certain collections were found which did not agree with any species described. A careful study of all the Northwestern and Pacific coast collections has led to the conclusion that all of the material examined on *P. acuminata, P. angustifolia, P. balsamifera* and *P. trichocarpa* from that region is identical and shows certain distinct morphological characters which enables it to be easily separated from *M. Medusæ* and *M. albertensis*. A diagnosis follows together with a list of the collections in the Arthur herbarium and those from Oregon in the herbarium of the writer.

Melampsora occidentalis sp. nov.

O & I. Pycnia and aecia uncertain, probably on Larix.

II. Uredinia chiefly hypophyllous, scattered, roundish, rather large, 0.5 to 1.5 mm. across, early naked, somewhat pulverulent, orange-yellow, fading to pale yellow, ruptured epidermis conspicuous; urediniospores oblong, ellipsoid or pyriform, 16 to 29 by 32 to 48 μ, slightly flattened laterally; wall colorless or slightly tinted with brown, 2 to 3 μ thick or up to 7 μ on the flattened sides; moderately and prominently verrucose-echinulate, without smooth spots, pores obscure; paraphyses numerous, intermixed with the spores, capitate or clavate, 16 to 24 by 42 to 77 μ, wall colorless, 2.5 to 3 μ thick, uniform, or thickened to 6 μ at apex.

III. Telia chiefly hypophyllous, scattered or more commonly crowded and sometimes confluent in groups surrounding the uredinia, irregularly rounded, small, 0.2 to 0.5 mm. across, slightly elevated at maturity, subepidermal, waxy, at first light cinnamon-brown becoming blackish brown; teliospores prismatic, 10 to 20 by 40 to 64 μ, wall cinnamon-brown, smooth, 1 to 2 μ thick, darker and thicker at apex, 3 to 5 μ; apical pore evident.

ON SALICACEÆ:

Populus acuminata Rydb., II, Stevensville, Montana, Sept. 10, 1908, D. B. Swingle *022;* II, III, Libby, Montana, Oct. 15, 1911, J. R. Weir *40.*

Populus angustifolia Jas., II, Livingston, Montana, Sept. 1, 1913, E. T. & E. Bartholomew (Barth. Fungi Colomb. *4332*, N. A. Ured, *1315*, as *M. Medusæ* Thüm.); II, III, Libby, Montana, Oct. 15, 1911, J. R. Weir; II, Big Horn Mts. Wyoming, Aug. 1898, Williams & Griffiths (Griff. West. Am. Fungi *369* as *M. populina* Lev.); II, III, Willis, Montana, Oct. 1888, J. W. Anderson; II, Seattle (?) Washington, 1906, Bonser *13;* II, Yosemite Valley, California, 1909, P. H. Rolfs.

Populus balsamifera L., III, Sour Dough Canon near Bozeman, Montana, Apr. 1, 1914, H. M. Jennison *88;* II, Sept. 4, 1913, E. Bartholomew (Barth. Fungi Colomb. *4548* as *M. albertensis*); Bremerton, Washington, Sept. 23, 1912, E. Bartholomew (Barth. Fungi Collomb. II, *4434*, III, *4435;* Barth. N. A. Ured. *806* as *M. Medusæ*); II, III, McCarthy Mts., near Willets, Montana, Oct. 1888, F. W. Anderson *383;* II, III, Leonia, Montana, Sept. 14, 1900, J. W. Blankenship *0253, 0254;* II, III, Kalispell, Montana, July 21, 1900, J. W. Blankenship *0255;* II, Caldwell, Idaho, Sept. 28, 1912, E. Bartholomew (Barth. Fungi Colomb. *4034* as *M. Medusæ*); II & III, Madison, Wisconsin, Oct. 14, 1910, E. T. Bartholomew (Barth. Fungi Colomb. *3915* as *M. Medusæ*).

Populus candicans Ait. II, III, Missoula, Montana, Oct. 10. 1898, Williams & Griffiths.

Populus trichocarpa Nutt., II, Corvallis, Benton Co., Oregon, Sept. 1909, H. S. Jackson *1069;* II, III, Oct. 15, 1912, H. S. Jackson *1024*, type; III, March 12, 1916 G. B. Posey; II, III, Trail to Sulphur Springs, Benton County, Oregon, Nov. 2, 1914, H. S. Jackson *3369;* II, Scott's North of Fort Klamath, Klamath Co., Oregon, Sept. 20, 1913, E. P. Meinecke *CrD2;* II, Clatskanie, Columbia Co., Oregon, Oct. 6, 1914, F. D. Bailey *3358;* Oct. 29, 1914, F. D. Bailey *3306;* II, III, Sumpter, Baker Co., Oregon; Aug. 21, 1915, J. R. Weir *265;* II, Medical Springs, Oregon; Aug. 1913, II, III, J. R. Weir *117;* II, Spokane Washington, July 1915, J. R. Weir *42;* II, III, Cour d'Alene, Idaho, Sept. 1915, J. R. Weir *72;* II, Libby, Montana, Oct. 15, 1915, J. R. Weir *40;* II, Pasadena California, Dec. 29, 1895, A. J. McClatchie; III, Foothills, near Stanford University, Santa Clara, California, April 1, 1902, C. F. Baker *435;* III, Seattle, Washington, Oct. 8, 1892, A. M. Parker *111;* Grizzly Trail, Beaver Valley, British Columbia, July, 1907, E. W. D. Holway; Puyallup, Washington, Aug. 23, 1909, E. Bartholomew (Barth. Fungi Columb. *4143* as *M. Medusæ*); Vernon, British Columbia, 1916, W. H. Brittain; Dillon, Montana, Aug. 3, 1914, J. R. Weir *37;* II, III, Leclede, Idaho, Sept. 1913, J. R. Weir *20.*

This species differs from all other species of Melampsora on Populus in the large size of the urediniospores which are only slightly flattened and are evenly verrucose-echinulate. The teliospores are much longer than those of *M. Medusæ* and are thickened at the apex. The character of the telial sori suggests that this species may be closely allied to *M. albertensis.* The sori are much larger as are also both uredinio- and teliospores.

This species may be the same as that recently cultured by Weir & Hubert[6] who used telial material from *P. trichocarpa* referred to *M. Medusæ* and obtained successful infection on *Larix europea* and *L. occidentalis.* The actual material used for infection and the aecia resulting have not been seen by the writer but telial material sent by Dr. Weir from Montana agrees with the form described above. Aecia from the same locality on *L. occidentalis* agree in general with aecia of *Melampsora Medusæ* and *M. Bigelowii.* The walls of the aeciospores are, however, somewhat thinner, 1 to 2 μ, and considerably thickened on opposite sides to 3 to 5 μ. They measure 17 to 19 by 19 to 26 μ. Additional culture work, and a careful comparison of the resulting aecia with those of *M. Medusæ* would be desirable. In any case, the morphological characters of the uredinial and telial stages are considered sufficient to warrant separation.

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[6] Phytopath. **7**: 108. 1917.

RELATION OF TEMPERATURE TO THE GROWTH AND INFECTING POWER OF FUSARIUM LINI

W. H. TISDALE

WITH PLATE XI AND ONE FIGURE IN THE TEXT

Studies on the nature and inheritance of resistance in flax to the wilt disease, caused by *Fusarium Lini* Bolley, were begun with the departments of plant pathology and experimental breeding of the University of Wisconsin in the winter of 1914–15. While growing plants in the greenhouse for these breeding experiments in the winter of 1915–16 the writer noted that marked differences existed in the rate of wilting of susceptible flax plants which were growing at different distances from the heating system. These observations, combined with temperature records, suggested the possibility that soil temperature might be one of the chief factors influencing the rate of infection of these plants. In order to determine this point experiments were arranged so that both the relation of temperature to the growth of the fungus in pure culture, and the relation of soil temperature to the infection of susceptible flax plants might be studied.[1]

RELATION OF TEMPERATURE TO THE GROWTH OF THE FUNGUS IN CULTURE

After ascertaining by careful measurement that actual correlation existed between soil temperatures and the rate of wilting of the flax plants, a study was undertaken of the relation of the fungus to various temperatures while growing in pure culture on artificial media. An investigation of this kind was considered of fundamental importance in order to work out and understand thoroughly the relation of soil temperature to infection. By using an incomplete series of temperatures ranging from 0 to 37°C. it was found that the organism failed to grow below 10°C. and at or above 37°C. This preliminary experiment showed approximately the temperature limits of the fungus and gave some indications as to what temperatures were best suited for its growth. Another experiment was arranged, using a more complete series of temperatures, in which plates

[1] The writer wishes to express his hearty appreciation to Professor H. L. Bolley of the North Dakota Agricultural Experiment Station for supplying flax seed and flax sick soil for the work. He is also indebted to Professor L. R. Jones of the University of Wisconsin for invaluable suggestions and kindly criticisms of the work as it progressed.

poured with a 1.8 per cent potato agar and inoculated in the center with bits of mycelium were incubated in duplicates at different temperatures for six days. After incubation the colony diameters were measured (table 1) and the plates arranged in a temperature series and photographed (plate XI). The plate numbers in table 1 correspond to the numbers in the photograph.

TABLE I

The effect of temperature on the growth of Fusarium Lini. Cultures six days old

PLATE NO.	TEMPERATURE	DIAMETER OF COLONY
	°C.	*mm.*
1	8.5–10	0
2	11	7
3	12–13	20
4	14	25
5	15	29
6	16	34
7	17	38
8	19	43
9	22	68
10	24–25	70
11	25–26	72
12	26–28	78
13	29–30	75
14	34	17
15	37	0

It appears from table 1 that the minimum temperature for growth of the fungus lies between 10° and 11°C., the optimum at about 26° to 28°C., and the maximum between 34° and 37°C. Another set of experiments showed that the fungus is able to grow slightly at a temperature ranging from 35° to 36°C. Judging from the vigor of the fungus at the various temperatures, it would be expected that flax plants would wilt more readily with soil temperatures between 20° and 30°C. This was actually found to be the case with susceptible plants growing in the greenhouse.

RELATION OF SOIL TEMPERATURE TO INFECTION[2]

While growing flax plants in the greenhouse for breeding experiments in the winter of 1915–16, as previously stated, a series of flats was placed near a system of heating pipes, while others were placed at a greater distance from the pipes where the temperature was lower. A more rapid

[2] Tisdale, W. H. Relation of soil temperature to the infection of flax by Fusarium Lini Boll. (Abst.) Phytopath **6**: 412. 1916.

wilting of susceptible plants was noticed in flats near the heating system. Soil temperatures were taken and it was found that the temperature in flats near the heating pipes ran at 18° to 20°C., while the temperature in flats farther from these pipes, where there was much less infection, ran at 14° to 17°C. This seemed to indicate that the critical temperature for the infection of flax by *Fusarium Lini* is somewhat below 17°C., which was of the more interest, in view of the fact that Gilman found that the lowest temperature for the infection of cabbage by *Fusarium conglutinans* Wr. is about 17°C.

Following these observations an attempt was made by controlling the soil temperature to determine more accurately the lowest temperature for infection of flax by *Fusarium Lini*. The first attempt was made by placing pots of infected soil containing germinating flax seeds in the cold-storage cellar near a small window where they could get light. Other pots planted at the same time were kept in the greenhouse as controls. The temperature in the cellar often ran below 10°C. during the nights. This temperature was too low for the plants to remain in a vigorous condition. The plants in the control pots began wilting in ten days and nineteen of the twenty-two plants were wilted at the end of twenty-two days, whereas none of the plants at the lower temperature in the cellar had wilted. The experiment was then terminated by a sudden drop in temperature which froze the plants in the cellar.

A second attempt was made at controlling the soil temperature by arranging a cool, circulating water jacket (fig. 1). A six-inch earthenware jar was filled about three-fourths full of infected soil and susceptible flax seeds planted. This jar was then supported in a larger jar, through which cold water flowed continuously, as shown in the figure. Seeds were planted in a similar jar and placed nearby at greenhouse temperature as a control. At the time these experiments were begun the temperature of the water was about 9°C. By careful regulation of the flow by means of the faucet valve it was possible to hold a fairly constant temperature between this point and the greenhouse temperature. A temperature ranging between 12° and 15°C. was maintained for eight days and the plants remained free from infection. The temperature was then raised to 16° to 17°C. for two days and lowered again to 12° to 15°C. Four of the twenty-three plants in the jar showed signs of the wilt within two days even at these low temperatures. Infection evidently occurred during the brief period at the higher temperature. The small earthenware jar was found to be unsatisfactory due to the fact that the material allowed too much condensation or seepage which kept the soil almost saturated. The experiment was then repeated with a glass battery jar substituted for the earthenware jar. The glass jar proved more satisfactory. In the second

experiment it was found that at temperatures below 15°C. no wilting of flax plants occurred, while plants in the control pot at temperatures ranging from 19° to 21°C. wilted rapidly. During the earlier part of this trial when the temperature was held at 13° to 14°C. the flax plants grew fairly well and no indications whatever of wilt were evident (fig. 1, A). After one month, when the temperature had risen to 15°C. only one plant of the twenty-one in the cold jar showed any sign of infection, while all of the thirty-three plants in the control jar were killed by wilt. The temperature in the cold jar could not be lowered as the water was warming up with the coming spring.

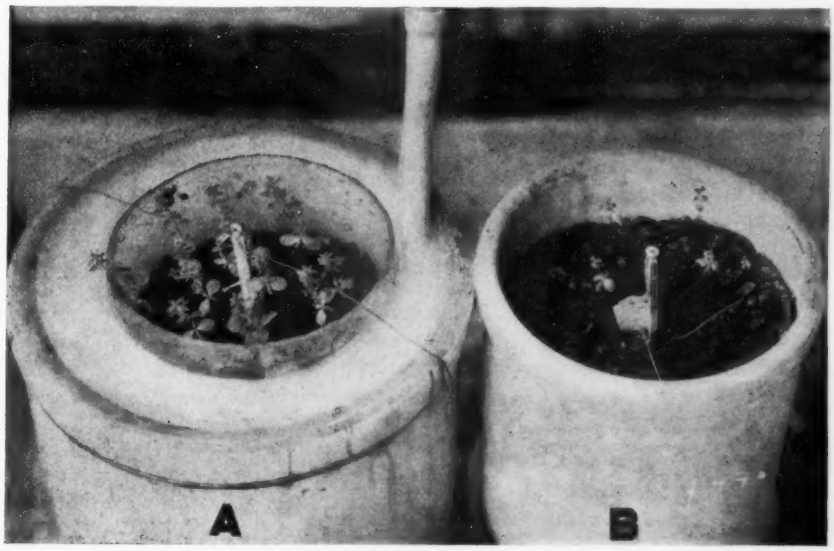

FIG. 1. RELATION OF TEMPERATURE TO THE INFECTION OF FLAX BY F. LINI

A, Susceptible flax plants growing at 13° to 15°C. in infected soil in a glass jar surrounded by running water. The smaller jar is supported by a glass tumbler inverted on the bottom of the larger jar. *B*, Susceptible plants growing in infected soil at greenhouse temperatures (19°–21°C.). Plants in this jar are practically all dead with wilt.

It seems from these experiments that the critical temperature for infection of flax by *Fusarium Lini* is between 14° and 16°C. This conclusion accords well with the previous evidence secured by culturing the fungus on agar at graduated temperatures. As stated in table 1 the minimum temperature was found to be 10° to 11°C. and reference to plate I will show that but little growth occurred below 15°C. We should expect the critical temperature for infection to be somewhat higher than the minimum tem-

perature at which the parasite will grow, especially since the host plant thrives well at the lower temperatures. In this case it seems clear that the host plant which is susceptible at the higher temperatures is able to resist or overcome whatever weak attempts at invasion the fungus can make at the lower temperatures.

The evidence here presented supplementing that secured by Gilman[3] should at least warrant further careful attention to the relation of temperatures to infection with the soil parasites, and especially the species of Fusarium.

CONCLUSIONS

1. *Fusarium Lini* grows on culture media at temperatures between 10° and 37°C., with its optimum temperature at 26° to 28°C.

2. Flax thrives well with soil temperatures as low as 13°C.

3. The critical temperature for the infection of flax by *Fusarium Lini* is about 15°C.

4. There is a close correlation between the temperatures at which *Fusarium Lini* grows best in pure culture and those at which flax wilt is most destructive.

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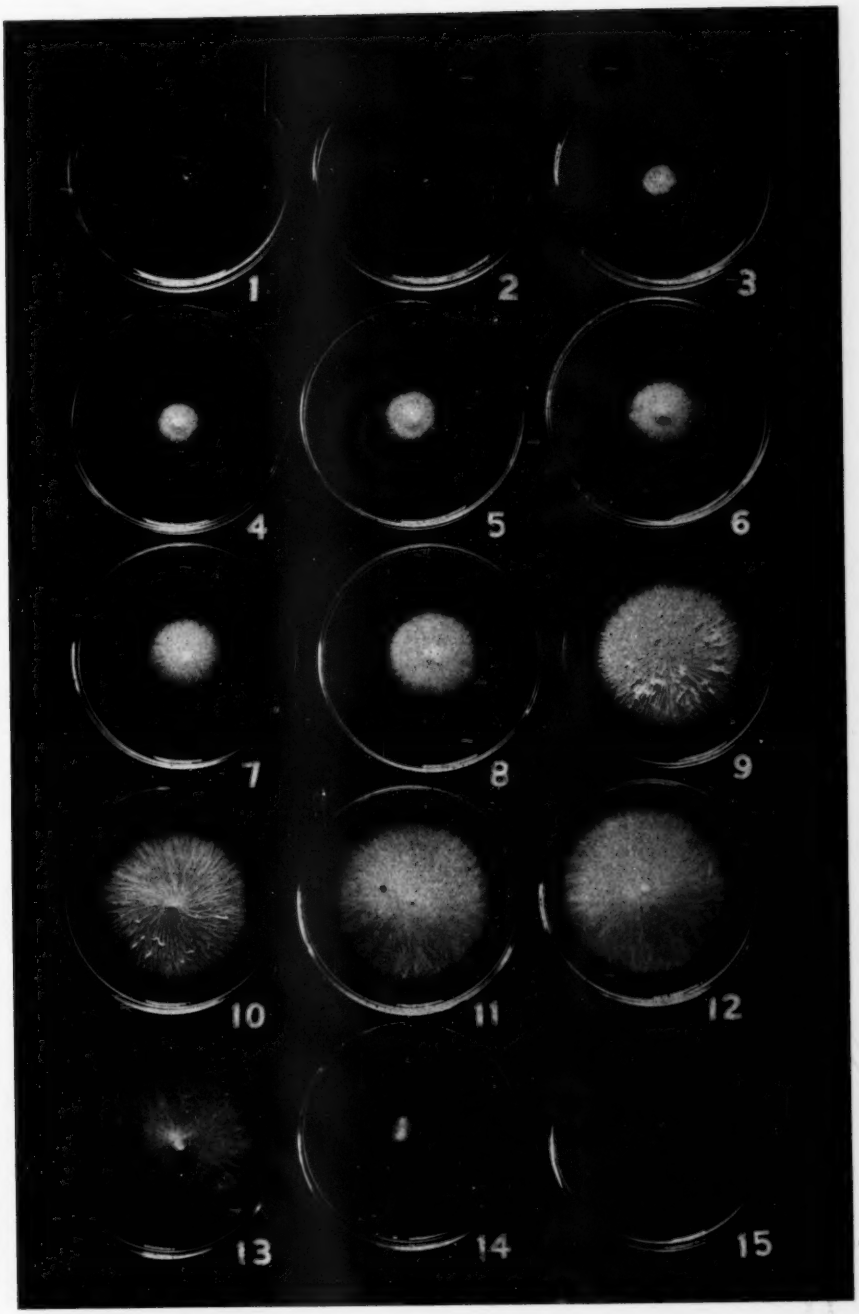
[3] Gilman, J. C. The relation of temperature to the infection of cabbage by Fusarium conglutinans Wollenw. Phytopath. **4**: 404. 1914.

—— Cabbage yellows and the relation of temperature to its occurrence. Ann. Missouri Bot. Gard. **3**: 25–84. 1916.

PLATE XI. RELATION OF TEMPERATURE TO THE GROWTH OF FUSARIUM LINI

These culture plates (1.8 per cent potato agar) were inoculated with much care as to uniformity and then incubated for six days at different temperatures, as follows: (1) 8.5–10°, (2) 11°, (3) 12–13°, (4) 14°, (5) 15°, (6) 16°, (7) 17°, (8) 19°, (9) 22° (10) 24–25°, (11) 25–26°, (12) 26–28°, (13) 29–30°, (14) 34°, (15) 37°.



TISDALE: RELATION OF TEMPERATURE TO INFECTION

A SIMPLE AND EFFECTIVE METHOD OF PROTECTING CITRUS FRUITS AGAINST STEM-END ROT

JOHN M. ROGERS AND F. S. EARLE

During the summer and fall of 1914, while studying the various rot organisms of citrus fruits at San Pedro, Isle of Pines, some very interesting facts were noted.

The percentage of rot in transit during the previous year was abnormally high and in the year of 1914 studies were made of the various conditions and organisms to ascertain the causes. It was decided at first that improper handling of the fruit had had much to do with the high percentage of decay during the season of 1913. In 1914, however, the fruit was handled in the most careful manner, having been picked under direct supervision of competent foremen, by laborers wearing cotton gloves. The fruit was placed in standard field crates and hauled to the packing house on wagons with bolster springs. The fruit was graded by expert graders and every doubtful fruit was culled out. Despite this careful handling a large amount of decay occurred in transit, but the rot was confined almost entirely to the variety of grapefruit known on the Isle of Pines as the Pinero or Native, a variety very similar to the Florida Triumph.

Counts were made of the rotten fruit from the culls and it was found that over eighty-three per cent of the rot was caused by a species of Diplodia. In many cases the organism had gained entrance through some injury, but in the majority of the fruit the rot started from the stem end with no apparent injury.

Inoculation experiments were made with the spores and hyphae of the Diplodia and it was found that perfectly sound fruit in all conditions of maturity could be rotted down through the stem end if moisture conditions were favorable. In this connection it was noted that the fruit that had been clipped showed more rot in the inoculation experiments than did the fruit that had been pulled, thereby removing the calyx. This was accounted for by the fact that the small cavities beneath the calyx under humid conditions, do not dry out quickly and make an excellent infection court. The small portion of stem left when the fruit was clipped, frequently became infected and through this source the infection entered the fruit. When the fruit was pulled the stem cavity had an opportunity

to dry quickly and there was less chance of spores lodging and germinating than where the calyx had not been removed.

With these facts in mind some method was sought of sealing the stem ends to prevent the entrance of the organism. Paraffin was first tried.

Fruit was gathered from trees in poor condition and showing some

TABLE 1

Showing numbers of fruits rotted on various dates in each of the lots

BEGINNING SEPTEMBER 20	LOT 1	LOT 2	LOT 3	LOT 4	LOT 5	LOT 6	LOT 7	LOT 8
September 27	1	0	0	1	0	0	0	0
October 4	3	0	2	0	2	0	0	0
October 10	7	2	5	1	1	1	0	0
October 14	2	4	0	0	2	0	0	0
October 16	1	0	1	0	0	1	0	1
October 20	0	0	0	0	0	0	0	0
November 1	2	2	3	1	1	0	0	1
November 10	1	0	4	2	0	1	2	0
November 19	0	0	1	1	2	0	0	0
Total	17	4	20	6	8	3	2	2

Diplodia die-back. Eight lots were made of twenty fruit each and treated in the following manner:

Lot 1. Fruit clipped and rind paraffined.
Lot 2. Fruit pulled and rind paraffined.
Lot 3. Fruit clipped. (Check.)
Lot 4. Fruit pulled. (Check.)
Lot 5. Fruit clipped, rind and stem end paraffined.
Lot 6. Fruit pulled, rind and stem end paraffined.
Lot 7. Fruit clipped, stem end paraffined and rind not paraffined.
Lot 8. Fruit pulled, stem end paraffined and rind not paraffined.

The number of rotted fruits was recorded and is shown in table 1.

Many decayed fruits appeared in the lots that were clipped and the results (table 1) substantiated previous knowledge of the fact that the clipped fruit did not hold up as well as pulled fruit. The difference between the pulled and the clipped lots is so great that it seems as though some other factor must have been partially responsible for the very high per cent of decay.

The treatment of the stem ends gave very promising results and the percentage of rot in the treated lots was greatly reduced. The paraffining of the rind gave no particular protection against rot, but this treatment did bring to light another point of much interest and economic value.

The fruit in the lots that had the rind paraffined did not shrivel and the rind did not dry out as did the other lots not so treated.

There have been two serious troubles in connection with the production of lemons on the Isle of Pines. These have been Diplodia stem-end rot, and the quick shriveling and drying of the fruits. The lemons are so thin-skinned that the rind dries out and becomes hard in a short period of time. By giving the fruits a good coating of paraffin it has been possible to keep them in excellent condition for from two to three months with practically no shriveling.

On October 17, 1915, lemon fruits were pulled and were divided into two lots of fifty fruits each. The stem ends of one lot were paraffined, the others were not. On January 24, 1916, there were a total of nine rotted

TABLE 2

Showing number of rotten fruit on various dates in each of the lots

BEGINNING NOVEMBER 19	LOT 1	LOT 2	LOT 3	LOT 4	LOT 5	LOT 6
December 10	0	4	20	16	8	18
December 30	0	8	8	6	6	8
January 26	1	3	18	4	4	10
Total	1	15	46	26	18	36

fruits in the paraffined lot and twenty-one in the untreated lot. These data and those in table 1 show clearly that the treatment of the stem ends is beneficial in the prevention of rot. Paraffin gave very promising results, but was not altogether satisfactory because it did not stick well and it was therefore difficult to seal the stem ends perfectly.

The next material to be tried was shellac. It was diluted to a thin consistency with alcohol. This material gave such satisfactory results that it was not necessary to seek further. It is easily and quickly applied, sticks well and seals the stem cavity perfectly.

The first experiment to be made with the shellac treatment consisted of six lots of fifty-six fruits each. The lots were treated as follows:

Lot 1. Fruit pulled and stem end shellacked.
Lot 2. Fruit clipped and stem end shellacked.
Lot 3. Fruit clipped and a cut made in the rind with a knife.
Lot 4. Fruit clipped, rind cut with a knife and shellacked. Stem end shellacked.
Lot 5. Fruit pulled. (Check.)
Lot 6. Fruit clipped. (Check.)

The number of rotted fruits was recorded on various dates and is shown in table 2.

The results shown in table 2 are very striking, particularly between lots 1 and 2, and 5 and 6. The results of lots 3 and 4 show that fresh injuries to the skin of the fruit can be protected to some degree by covering the injury with a thin coating of shellac. Better results would have

TABLE 3

Showing number of rotten fruit on various dates in each of the lots

BEGINNING DECEMBER 12	LOT 1	LOT 2	LOT 3	LOT 4	LOT 5	LOT 6
Native grapefruit						
December 20	0	1	1	2	1	2
January 15	0	1	3	5	1	1
February 4	1	2	1	0	0	3
Total	1	4	5	7	2	6
Walter's grapefruit						
December 20	0	0	2	1	0	0
January 15	0	2	1	2	1	2
February 4	1	2	1	2	0	1
Total	1	4	4	5	1	3
Valencia oranges						
December 24	0	0	0	1	0	0
January 15	0	1	2	2	0	0
February 4	0	1	1	3	0	1
Total	0	2	3	6	0	1
Villa Franca lemon						
December 24	0	0	1	1	0	0
January 15	0	1	0	1	0	0
February 4	0	0	1	2	0	1
Total	0	1	2	4	0	1
Persian lime						
December 24	0	6	0	0	0	2
January 15	0	0	2	6	5	4
February 4	1	2	0	2	0	1
Total	1	8	2	8	5	7

undoubtedly been secured in these lots had the fruit been pulled instead of being clipped.

The next experiment was made in order to determine the effectiveness of the treatment on the various kinds of citrus fruits. Twenty fruit were used in each lot and the lots treated as follows:

Lot 1. Fruit pulled, stem ends shellacked, dipped in a suspension of spores of Diplodia.
Lot 2. Fruit clipped, stem ends shellacked, dipped in a suspension of spores of Diplodia.
Lot 3. Fruit pulled and dipped in suspension of Diplodia spores.
Lot 4. Fruit clipped and dipped in suspension of Diplodia spores.
Lot 5. Fruit pulled. (Check.)
Lot 6. Fruit clipped. (Check.)

The results of the experiment are shown in table 3.

The results of the experiment show that the fruits of some varieties and species of Citrus are more subject to the Diplodia rot than others, but that the treatment is just as effective in all cases. The Native grapefruit and the Persian lime showed the highest percentage of rot in this experiment, but the lemon has been found to be very subject to the Diplodia rot, particularly during the curing process.

The fruit when dipped in an aqueous suspension of Diplodia spores showed more rot than the check lot. The shellac gave protection even when the fruit was dipped in the spore suspension.

In the next experiment two boxes of Native grapefruit were sent to Dr. C. L. Shear, Washington, D. C. The fruit was packed and in transit fully two weeks before being opened. It was fully ripe when picked, in fact, some of it was nearly ready to drop from the tree and the trees were in more or less weakened condition from Diplodia die-back disease. This was the most severe test that the shellacking treatment could be subjected to, as the fruit was too ripe to warrant shipping.

One box of fruits was washed by the overhead sprinkler and revolving brush system, with clean running water, no soaking tank being used. Half of the fruit in this box was shellacked and the other half was not. The second box, after being run through the sizers and polishers, was packed dry. Half of the fruit in this box was shellacked and half was not. The fruit in all four lots was pulled. The results, as tabulated by Doctor Shear, appear in table 4.

The results shown in this table were most satisfactory from several standpoints. The shellacking treatment reduced the amount of rot over 25 per cent in both the dry and the washed lots. Washing fruit, even with clear running water, greatly increases the amount of rot from the stem-end organism on many kinds of citrus fruits.

TABLE 4

Report on grapefruit received from Mr. Rogers, February 7, 1917

DATE	DRY		WASHED	
	Stem end shellacked (48)	End not shellacked (48)	Stem end shellacked (56)	End not shellacked (56)
February 9, 1917.	1 rotten. Started in wound	1 rotten. Wholly rotten covered with Penicillium*	1 rotten. Wholly rotten. Seems to have started from wound	17 rotten. 10 all rotten. Penicillium present; 7 partly rotten. Decay apparently at stem end
February 19, 1917	0	4 rotten. 3 apparently started from stem end. 1 from wound; all show Penicillium	3 rotten. 2 rotten, began at stem end. 1 began at bottom end	7 rotten. 5 involve stem end; 2 entirely rotten show Penicillium
March 1, 1917....	1 rotten	3 rotten	4 rotten	13 rotten. 6 all rotten; 5 stem-end-rot; 2 doubtful
March 10, 1917...	2 rotten	7 rotten. 5 typical Diplodia rot	3 rotten	2 rotten
Total.....	4	15	11	39

* The presence of the Penicillium mentioned does not necessarily indicate that this was the primary cause of rot. It probably followed and obscured the Diplodia.

SUMMARY

Citrus fruits subject to stem-end rot may be protected to a great degree by shellacking the stem end.

If the shellacking treatment is to be most effective, it is necessary that the fruit be pulled and not clipped. In this connection it should be stated that the pulling of grapefruit without tearing a portion of the rind is a difficult undertaking, though it can be accomplished. Oranges, lemons and limes may be pulled more easily than clipped and with no injury to the rind.

Washing the fruit increases the amount of decay to a very great extent. The use of a soaking tank, where the stem-end rot organism is present, is the greatest possible folly.

A stemless lemon, having been pulled and shellacked, will hold up as long as a lemon with the stem intact.

Fruit may be practically guaranteed against rot if given this treatment and handled properly.

Avocados, watermelons and other fruits could possibly be protected against stem-end rot if given this treatment.

Some citrus fruits are more subject to the attacks of Diplodia rot than others. In this locality the Pinero or Native grapefruit, the Persian lime and the Villa Franca lemon suffer most from this rot.

A thin coat of paraffin prevents shriveling and drying, and keeps the fruit in a marketable condition from a month to six weeks longer than fruit not so treated.

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ARTHROPODS AND GASTEROPODS AS CARRIERS OF CRONARTIUM RIBICOLA IN GREENHOUSES

G. Flippo Gravatt and Rush P. Marshall

The literature on dissemination of fungi in general by insects has been recently summarized by Studhalter and Ruggles.[1] Numerous writers have called attention to insects as possible carriers of rust spores, or have shown that rust spores actually were so carried. Wolf[2] notes that vast numbers of urediniospores of the morning glory rust, *Puccinia cassipes* B. & C., were present in the fecal deposits of a katydid. So far as can be determined no previous information has been noted on the dissemination of rust fungi by Gasteropods.

Studies with insects, sow bugs, and snails allowed to feed on various species of the genus Ribes grown for inoculation experiments with *Cronartium ribicola* Fisch. in the pathological greenhouses at Washington, D. C. during the past winter, have shown that these animals have a decided preference for the infected leaves. Observation indicated that the greater part of the feeding was done by a greenhouse weevil, but on leaves growing close to the ground, snails, slugs, and sow bugs were perhaps more active. A small slug was observed eating the telial columns of *Cronartium ribicola* from the under side of a black currant. Apparently, the uredinial pustules and the leaf tissue were untouched. Judging by the thorough manner in which the telial columns had been eaten off the leaves of this bush, the slug had been at work for some days. In the greenhouse, on a white pine (*Pinus strobus*), infected by *Cronartium ribicola*, a sow bug has been observed eating out pycnial pustules and the surrounding tissue of the blister-rust swellings.

SPORES ON THE BODIES OF ANIMALS

Ants, weevils, and one slug were collected directly from infected plants in the greenhouse. In most cases, however, the suspects were confined on Ribes bushes under bell glasses or in dishes with infected leaves. Each individual was removed from the leaves with flamed tweezers to a small

[1] Studhalter, R. A., and Ruggles, A. C. Insects as carriers of the chestnut blight fungus. Pennsylvania Dept. Forestry Bul. **12**: 33, 4 *pl.* 1915.

[2] Wolf, F. A. Further studies on peanut leafspot. Jour. Agr. Research **5**: 891–902. 1916.

TABLE 1

Examination for spores of Cronartium ribicola on the bodies of animals

DATE 1917	ANIMAL*	PLACE COLLECTED OR CONFINED	TOTAL NUMBER UREDINOSPORES IN WASH WATER	NUMBER SPORIDIA FROM TELIAL COLUMNS IN WASH WATER
January 11.....	1 weevil, *Pantomorus fulleri*	On infected Ribes plant under bell jar	21	2
January 11.....	1 weevil, *Pantomorus fulleri*	On infected Ribes plant under bell jar	85	10
January 24.....	1 weevil, *Pantomorus fulleri*	Confined in dish with infected leaves	425	0
January 31.....	1 slug, *Agriolimax agrestis*	Confined in dish with infected leaves	0	0
January 27.....	1 slug, *Agriolimax agrestis*	On infected plant in greenhouse	10	110
January 10.....	5 red ants, *Pheidole anastassii*	On infected plant in greenhouse	25	0
January 17.....	12 red ants, *Pheidole anastassii*	On infected plant in greenhouse	200	0
January 25.....	1 red ant, *Pheidole anastassii*	Confined in dish with infected leaves	0	8
January 25.....	1 red ant, *Pheidole anastassii*	As above	5	135
January 25.....	1 red ant, *Pheidole anastassii*	As above	0	220
January 25.....	1 red ant, *Pheidole anastassii*	As above	0	0
January 25.....	1 red ant, *Pheidole anastassii*	As above	0	20
January 25.....	1 sow bug, *Armadillidium vulgare*	As above	3	85
January 25.....	1 sow bug, *Armadillidium vulgare*	As above	0	450
February 2.....	1 sow bug, *Armadillidium vulgare*	As above	27	0
February 25.....	1 small spider	As above	0	30

* Identifications through the kindness of Paul Bartsch, W. Dwight Pierce and J. R. Horton.

TABLE 2

Tests of adherence of spores to bodies of animals

ANIMAL	TREATMENT AFTER BEING DIPPED	NUMBER DAYS BETWEEN TREATMENT AND EXAMINATION	UREDINOSPORES ON BODY	SPORIDIA ON BODY	PROMYCELIA OR TELIAL COLUMNS
Sow bug, *Armadillidium vulgare*	In petri dish on filter paper	1	2	35	4 promycelia, 1 telial column
Sow bug, *Armadillidium vulgare*	In petri dish on filter paper Transferred to clean quarters on second day	7	0	13*	
Sow bug, *Armadillidium vulgare*	In beaker with soil bottom	2	5	17	
Sow bug, *Armadillidium vulgare*	In beaker with soil bottom Transferred to clean soil on second day	7	0	2*	
Cockroach, *Blatta orientalis*	In petri dish with filter paper	1	4	20	
Cockroach, *Blatta orientalis*	In petri dish with filter paper Transferred to clean quarters on second day	2	0	0	
Cockroach, *Blatta orientalis*	Transferred to clean quarters on second day	4	0	0	
Red ant, *Pheidole anastassii*	On soil	1	4	10*	
Red ant, *Pheidole anastassii*	On soil	2	0	6	

* Several sporidia in these counts were partially germinated. A number of the sporidia were in this condition when insects were treated.

vial containing a measured quantity of distilled water and thoroughly washed to free any adhering spores.

At least one-tenth of the water secured from the first washing was examined under the microscope, and the spores counted. This result was compared with the examination of the wash water as a whole. In a few cases modifications were made of the results obtained by counting one-tenth of the total amount. The figures given in the tables are only approximately accurate, due to the method of counting and the fact that all of the spores were not removed from the bodies by the first washing.

TABLE 3

Examinations for spores of Cronartium ribicola in excreta

DATE 1917	ANIMAL	LOCATION OF ANIMAL BEFORE EXAMINATION	UREDINOSPORES	SPORIDIA	PARTS OF TELIAL COLUMNS
January 11.....	Weevil, *Pantomorus fulleri*	On Ribes bush under bell jar	120	0	
January 11.....	Weevil, *Pantomorus fulleri*	On Ribes bush under bell jar	10	0	
January 12.....	Weevil, *Pantomorus fulleri*	On Ribes bush under bell jar	1,870	210	
January 12.....	Weevil, *Pantomorus fulleri*	On Ribes bush under bell jar	780	0	
January 12.....	Weevil, *Pantomorus fulleri*	On Ribes bush under bell jar	400	60	
January 12.....	Weevil, *Pantomorus fulleri*	On Ribes bush under bell jar	210	0	
January 27.....	Slug, *Agriolimax agrestis*	On Ribes bush in greenhouse	7	17	16
January 27.....	Slug, *Agriolimax agrestis*	On Ribes bush in greenhouse	7	28	28
January 27.....	Slug, *Agriolimax agrestis*	On Ribes bush in greenhouse	20	180	128
January 27.....	Slug, *Agriolimax agrestis*	On Ribes bush in greenhouse	8	65	96
February 15.....	Slug, *Agriolimax agrestis*	Confined on infected leaves	1,050	0	
February 15.....	Slug, *Agriolimax agrestis*	Confined on infected leaves	960	0	
February 15.....	Slug, *Agriolimax agrestis*	Confined on infected leaves	120	0	
February 3.....	Snail, *Subulina octona*	Confined on infected leaves	2	0	
February 3.....	Snail, *Subulina octona*	Confined on infected leaves	9	0	
February 3.....	Snail, *Subulina octona*	Confined on infected leaves	50	0	
February 3.....	Snail, *Subulina octona*	Confined on infected leaves	0	0	
February 3.....	Snail, *Subulina octona*	Confined on infected leaves	60	0	
February 3.....	Snail, *Subulina octona*	Confined on infected leaves	30	0	
February 2.....	Sow bug, *Armadillidium vulgare*	Confined on infected leaves	750	0	
February 2.....	Sow bug, *Armadillidium vulgare*	Confined on infected leaves	300	0	

Several ants, sow bugs, and cockroaches were thoroughly shaken in a water suspension of urediniospores and sporidia and after being dried were confined in various dishes to determine how long, under certain conditions, the spores would remain on their bodies. The methods used in making examination for spores were the same as those previously given.

SPORES IN EXCRETA

In determining if the entire spores pass through the alimentary tract, the animals tested were either taken while feeding on diseased plants in the greenhouse, or were confined with fungus-bearing material. After being thoroughly washed in several changes of distilled water to remove any adhering spores, they were confined in petri dishes with blotting paper in the bottom to collect excreta. Deposits were removed singly and each macerated in a small quantity, usually ten drops, of distilled water. At least one-tenth of this was carefully examined under the microscope for spores. When the count was not high the entire quantity was examined, rather than a part. Due to the difficulty in counting, and the fact that in many cases only a portion of the material was used, counts were only approximately accurate.

VIABILITY OF EXCRETED SPORES

Germination tests were made of the urediniospores recovered from each excretal deposit, using distilled water at about 13°C. in watch glasses or hanging-drop cells. Of the urediniospores, only those passed by the slug in the first and second pellets of February 5, 1917 gave germinations. The results showed less than one per cent germination, which is considerably lower than the average germination secured with spores of the same age when taken directly from infected leaves. Alternaría spores which passed through the sow bug on February 3, 1917 showed abundant germination. Inoculations made from the first and second pellets of the weevil, collected January 12, 1917 gave positive results when inoculated on one unidentified western species of *Ribes*. Another western species and two plants of *Ribes tenuifolium*, together with the check, remained healthy.

The four excretal deposits obtained on January 27, 1917 from the slug were composed by volume, respectively, of 25, 33, and 95 per cent of parts of telial columns. Germination tests of these portions of telial columns gave an average germination of only a little over three per cent, considering the germination of teliospores of a column as the unit. Nearly all of these columns had been cut into several pieces by the slug. Tests made with fresh, whole, telial columns and with fresh, broken, columns show only slight differences in the percentages obtained. As the average ger-

mination of telial columns tested a week after they were removed from the leaf is above 50 per cent, it may be concluded that alimentation greatly lessens the viability of the teliospores.

DISCUSSION

Cronartium ribicola produces abundant urediniospores and teliospores under greenhouse conditions but spreads very slightly during the winter, the new infections being confined to infected plants having leaves within an inch or less of the ground, where moisture remains on leaves for some time after watering. The importance of Arthropods and Gasteropods in causing new infections of the fungus in the greenhouse is probably very slight.

In the field, wind must play the major part in the dissemination of *Cronartium ribicola*, as various tests in and around a diseased Ribes planting show that urediniospores are in the air in decreasing frequency up to fifty feet from the nearest bush and, of course, are carried by strong winds for indefinite distances. However, it seems fairly certain from these results obtained with *C. ribicola*, and those of other investigators of insects and birds with various fungi, that animals are important agents in the dissemination and spread of this fungus.

SUMMARY

1. The small animals tested were bearers of numerous urediniospores and sporidia of *Cronartium ribicola*.

2. Urediniospores and sporidia will adhere to bodies of the animals under certain conditions for at least a week.

3. Small animals feed on the different spore-stages of the blister-rust fungus. Their excreta contain abundant urediniospores and in some cases sporidia and pieces of telial columns.

4. Alimentation lessens the viability of both the uredinio- and teliospores.

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PRELIMINARY REPORT ON THE VERTICAL DISTRIBUTION OF FUSARIUM IN SOIL[1]

MINNIE W. TAYLOR

For the past three years considerable difficulty has been experienced with the damping-off of seedlings of *Pinus resinosa* Ait. and *P. ponderosa* Dougl. in the seed-beds of the pine tree nursery at the Metcalf Botanical Garden of Brown University, Providence, Rhode Island.

The Botanical Garden was originally farm land. It has been uncultivated for some time although the hay is cut each year. The top soil is moderately light colored, sandy loam about 14 inches deep. Below this there is a bed of light yellow, coarse sand from 4 to 10 feet deep underlaid by hard pan. The land in the vicinity of the seed-beds slopes very gently to the northeast.

So far as the writer can learn *Fusarium* has never been definitely reported much more than 7 inches below the surface of the ground. The lowest depth at which Jensen[2] collected soil samples appears to have been 8 inches, but there is no specific mention at what depths the various fungi occurred. Waksman[3] in speaking of the depths at which fungi, including *Fusarium*, were found states that "most of the other organisms were isolated from the upper 8 inches of soil," but as he does not say just what these were, it is impossible to tell whether *Fusarium* was in this group. Beckwith[4] collected all of his samples of soil 2 inches below the surface. Manns[5] mentions experiments with "sick soil" in the greenhouse, but does not state that the soil was taken at any particular depth. He believes that the rate of penetration of *Fusarium* through the soil depends upon the species of *Fusarium*, that of potato blight being

[1] The investigation was conducted in the laboratory of the Botanical Department of Brown University, during the year 1915–1916, as a partial fulfillment for the degree of Master of Arts. The writer wishes to express her appreciation to Dr. Harlan H. York for his kind direction and assistance during the progress of the work.

[2] Jensen. C. N. Fungous flora of the soil. Cornell Agr. Exp. Sta. Bul. 315. 1912.

[3] Waksman, Selma A. Do fungi live and produce mycelium in the soil? Science, n.s. **44**: 320–322. 1916.

[4] Beckwith, T. D. Root and culm infection of wheat by soil fungi in North Dakota. Phytopath. **1**: 169–176. 1911.

[5] Manns, T. F. Fusarium blight and dry-rot of the potato. Ohio Agr. Exp. Sta. Bul. 229. 1911.

slower than that of flax wilt or cabbage wilt. Werkenthin[6] took samples from 1 to 7 inches below the surface and says that "in deeper regions below 4 inches, no viable fungous spores seem to be present." He adds that "of special interest in the study of soil fungi is the fact that the virgin soil contained fungi which are known to be parasitic to cultivated plants, e.g., *Fusarium Solani* (Mart.) Sacc., *F. oxysporum* Schlecht. and *F. radicicola* Wollenweber." In summarizing he says that "pathogenic fungi, especially species of *Fusarium*, live in the soil as saprophytes throughout the winter."

In a large number of cultures, on nutrient agar, which have been made from pine seedlings that had damped off, *Fusarium* sp.[7] was the only fungus found that is known to cause damping-off. Moreover, it was observed that in the seed-beds made from sand taken 18 to 24 inches below the surface of the ground, damping-off occurred just as abundantly apparently as in the beds made from surface soil.

The beds in all instances were made in the usual way. Because of this fact, the present problem was suggested, namely to determine to what depth *Fusarium* occurs in the soil of the nursery and also whether it is present at different places in the grassland surrounding the nursery. The following is merely a preliminary report, the first to be made on the results of a series of investigations.

METHODS

Six lots of soil *A*, *B*, *C*, *D*, *E* and *F*, were collected. The first three lots were taken in November and the fourth in December, 1915, the fifth in January and the sixth in March, 1916.

Trenches were dug varying from 12 to 34 inches in depth, one trench for each lot. Soil samples were collected from the upper side of undercuts in the sides of the trenches at intervals of about 2 inches, from the surface of the ground down to the bottom of the trench. Lot *A* was taken from the grassland about 10 feet north of the northwest corner of the nursery. Lot *B* also came from the grassland 100 feet north of the northwest corner of the nursery. Lot *C* was taken from a seed-bed of *Pinus resinosa*, planted in 1914 in which all the seedlings had "damped off." It was neither planted nor cultivated in 1915 and contained no green plants. Lot *D* consisted of samples taken no deeper than 12 inches from a white pine grove several miles from the garden. *E* was collected in a

[6] Werkenthin, Frederick C. Fungous flora of Texas soils. Phytopath. **6**: 241–253. 1916.

[7] In the preliminary experiments no attempt was made to determine the species of *Fusarium*. Consequently the term *Fusarium* as used in this paper is to be taken in the collective generic sense.

portion of a transplant bed which was made in 1914 and in which the trees had died from drought. This plot although cultivated in the season of 1915 contained no seed plants of any sort. Lot *F* was taken about 4 feet from *E* in the same sort of soil.

In the digging of the various trenches no precautions were taken against contamination from the air with the exception that the collections were made as soon as possible after the earth was exposed so that the sterilized boxes in which the soil was placed were not open to the air any longer than was absolutely necessary.

TABLE 1

Showing depths at which samples were collected and in which Fusarium occurred

A 9N15 Grassland	B 12N15 Grassland	C 23N15 Seed-bed	D 5D15 White-Pine Grove	E 24Ja16 Transplant Bed	F 15Mr16 Transplant Bed
Surface	Surface	Surface*	Surface	Surface	Surface
2 inches*	3 inches*	1 inch*			
3	5	2 inches	2 inches		2 inches*
5	6	3*	4	2 inches*	4*
8	8	4	6	4	6*
10	10	6	8	6	8*
12	11	8	10	8	10*
14	13	10*	12	10	12*
16	14	12		12*	14*
20*	16	14		14	16*
24	18	16		16*	18*
	20	18		20	20*
	22	20		24	22*
	24	22		28	24*
	26	24		34	26*
		26			
		28			
		30			

* Samples in which *Fusarium* occurred.

Two kinds of culture media were used, oatmeal agar and soil agar, the former on the whole appearing to give the better results. The soil agar was made according to the second formula described by Jensen. Although this medium was very satisfactory there was apparently too little difference in the reaction of the fungi toward it to pay for the additional time in preparing it. Practically the only advantage was that a more rosy color was produced by the *Fusarium* on the soil agar than on the oatmeal agar.

The cultures were made in the following manner: about 1 gram of soil from each sample was shaken up with 100 cc. of distilled water in a steril-

ized bottle. With a sterilized pipette 1 cc. of the solution was taken from each bottle, added to 10 cc. of melted agar and plated. Two plates were usually made from each bottle. The samples of lots *E* and *F* were placed in sterilized glass jars and thoroughly shaken to mix the soil well before making the solutions. At first the solutions were allowed to settle five minutes before pipetting off, but in *E* and *F* the 1 cc. was taken immediately after the solution had been well shaken. There was practically no difference in the number of colonies produced by the two methods. When fungous colonies appeared in the plates isolations were made in the usual manner for obtaining pure cultures.

RESULTS

As was to be expected a great variety of fungi developed in culture. *Fusarium* was found in the cultures from the soil taken both from the nursery and the grassland; in the nursery *Fusarium* occurred practically at all depths examined, not in all lots, from the surface to a depth of 24 inches, while in the grassland it was found at only three depths, 2, 3 and 20 inches. The finding of *Fusarium* in the cultures made from the soil of lot *A* taken at 20 inches from the grassland may have been the result of contamination although every precaution was taken to prevent it.

In lot *A* *Fusarium* was found at 2 and 20 inches below the surface; in *B* at 3 inches below; lot *C*, at the surface, 1, 3, and 10 inches. Micro- and macrospores were found in lots *A*, *B* and *C*. No fungi which are known to cause "damping-off" were found in lot *D*. In *E*, *Fusarium* occurred at 2, 12 and 16 inches and in these cultures many chlamydospores were observed as well as micro- and macrospores. *Fusarium* was found in lot *F* at every depth examined from 2 inches down to 24 inches, micro- and macrospores being most abundant, and chlamydospores fewer than in the cultures from lot *E*.

A possible explanation for the occurrence of *Fusarium* at the lower depths is that it may follow down living roots of such plants as clover and grasses as a parasite or the dead roots as a saprophyte. Sackett[8] believes that the character of the soil influences the depths at which bacteria occur; possibly the same is true of fungi. In arable soil Sackett finds that bacteria occur most abundantly in the first 7 or 8 inches, while in soil whose texture is loose and open they are found at lower depths. In irrigated soil he states that bacteria are carried down to a depth of 8 to 10 feet by irrigation water and alfalfa roots, and that in compact soil the lower limit is much nearer the surface.

[8] Sackett, W. G. Some soil changes produced by microorganisms. Colorado Agr. Exp. Sta. Bul. 196. 1914.

Moreover, it is probable that other agencies such as spiders, earthworms and larvae of May-beetles and other insects play a considerable part in the distribution of fungi in the soil, since spores may be carried down on their bodies or may be washed down through their tunnels from above. Earthworms and larvae of insects were found at the lowest depths at which soil was taken and cultures made from the contents of the alimentary canals of two earthworms revealed the presence of *Fusarium*.

Bolley[9] believes that a certain amount of moisture is necessary for a large development of certain fungi in the soil and mentions drainage water as a means of distribution.

Various investigators consider climate an important factor in connection with soil fungi.

Beckwith thinks it is possible that climatic conditions may influence "the mycological floras both saprophytic and parasitic."

Conn[10] finds more bacteria present in frozen soil than in unfrozen soil and points out the need of investigation along the line of seasonal variation among soil bacteria.

The results obtained by the writer also seem to indicate a possible seasonal variation of fungi since *Fusarium* occurred at so many more depths in March than during the previous winter months. It is also evident that what is true for bacteria may not necessarily be true for fungi as more *Fusarium* was found in unfrozen than in frozen soil. The question of seasonal variation of soil fungi is receiving further investigation which is to be reported later.

SUMMARY

1. Preliminary investigations to determine the depth to which *Fusarium* is present in soil indicate that *Fusarium* occurred to a depth of 24 inches in the nursery soil.

2. *Fusarium* occurred in more samples of soil from the nursery than from the grassland.

3. *Fusarium* appeared in culture from more samples in March than in the previous winter months indicating a possible seasonal variation.

[9] Bolley, H. L. Flax wilt and flax sick soil. North Dakota Agr. Exp. Sta. Bul. 50. 1901.

[10] Conn, H. Joel. Bacteria in frozen soil. New York (Geneva) Agr. Exp. Sta. Tech. Bul. 35. 1914.

BRIEFER ARTICLES

NOTES ON WOOD-DESTROYING FUNGI WHICH GROW ON BOTH CONIFEROUS AND DECIDUOUS TREES. II.

JAMES R. WEIR

Since the appearance of number I of this series,[1] additional collections of fungi growing on the wood of both coniferous and deciduous trees have been made. Correspondents have also contributed several interesting specimens with notes on host, range, and general habits of growth.

The mere listing of unreported hosts for saprophytic wood-destroying fungi which may occur on any woody substratum in the absence of the typical or common host is in most cases of mycological interest only, provided the species are correctly interpreted and a nomenclature of recognized standing employed. The preparation of such lists possibly serves a useful purpose, if much material is handled, in that it brings the collector to the realization that a new species does not lurk in every unusual form encountered. A thorough understanding, on the other hand, of the host relations of wound parasites is of great economic importance, for on this may be based plans for the proper silvicultural management of mixed forests. It is also of interest to note the occurrence on coniferous wood of fungi commonly found on the wood of dicotyledoneous trees which, although of no practical importance so far as wound parasites are concerned, may be so considered with respect to the destruction of fallen timber. It is to be noticed that a greater number of fungi commonly associated with the wood of deciduous trees is found on coniferous wood than is the reverse. This is particularly true in Western United States where great bodies of pure coniferous forests exist.

Dædalea confragosa (Bolt.) Fr. on branches of *Abies grandis*, Bellingham, Washington. Owing to the fact that the fungus is so closely associated with deciduous trees, especially willows and birches, its discovery on coniferous wood is surprising. The fungus was abundant on its usual hosts at Bellingham. The specimen collected is of the form known as *Trametes rubescens* (A. & S.).

Dædalea unicolor (Bull.) Fr. on fallen branches of *Abies lasiocarpa*, Priest River, Idaho. Semi-stipitate form but otherwise typical.

Irpex lacteus Fr. on *Betula occidentalis*, Priest River, Idaho. Speci-

[1] Weir, James R. Notes on wood-destroying fungi which grow on both coniferous and deciduous trees. I. Phytopath. **4**:271-276. 1914.

men collected and contributed by J. Huot. Fungus usually occurs in this region on Tsuga, Abies, and Picea.

Polyporus albellus Peck, a common birch wood fungus in the Northwest, has been collected once at Laclede, Idaho, on dead branches of *Abies grandis*.

Polyporus elegans (Bull.) Fr., usually on soft wood of deciduous trees, collected on branches of *Tsuga heterophylla*, Priest River, Idaho.

Polystictus abietinus (Dick.) Fr., small specimens on *Populus trichocarpa*. Typical.

Schizophyllum commune Fr. on *Tsuga heterophylla*, Seattle, Washington. Specimen contributed by Dr. J. W. Hotson.

Trametes carnea (Nees) Cooke, on fallen trunk of *Arbutus menziesii*, Grants Pass, Oregon. One small sporophore. Species is usually zonate. Collection has no surface markings but otherwise typical.

Trametes heteromorpha (Fr.) (*Lenzites heteromorpha Fr.*) (*Dædalea heteromorpha* Fr.) This plant usually grows on coniferous wood but is found occasionally on Alnus. Lloyd[2] recently described a new species (*Trametes lacerata*) collected on Alnus which probably belongs here. The pores of *Trametes heteromorpha* are very variable. It is very seldom a true Lenzites and is a better Trametes.

Trametes hispida Bagl. on *Pseudotsuga taxifolia*. Contributed by Dr. J. W. Hotson, Seattle, Washington. Very unusual host. In America, practically confined to Populus and Salix. Collected by the writer in Europe (Bavaria) on Fraxinus. Other collections by the writer in Bavaria and Serbia are closer to the American plant known as *Trametes peckii* Kalch. than any European material so far examined. In view of the fact that the European plant has usually smaller pores, is thinner, and of a distinctive brown color, it may cause less confusion if the two forms are held distinct. American plants in the writer's herbarium referred by Peck to *Trametes trogii* Berk. more nearly represent the European plant in this country.

Trametes serialis Fr. is usually found on coniferous wood. Specimens in the writer's herbarium are labeled "Collected on *Populus tremuloides*, Gila National Forest, New Mexico." The name of the collector is not given. The specimens have smaller pores than is usually the case.

Trametes variiformis Peck, on *Betula occidentalis*, Bellingham, Washington. This species may be considered a rare fungus even on coniferous wood.

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[2] Lloyd, C. G. Mycological Notes. No. 43, p. 604. 1916.

THE SPRAY METHOD OF APPLYING CONCENTRATED FORMALDEHYDE SOLUTION IN THE CONTROL OF OAT SMUT

R. J. HASKELL

The treatment of oat seed for the control of the smut diseases, caused by *Ustilago avenae* and *U. lævis* was placed on a commercial basis at least in North America when Bolley[1] announced the effectiveness of dilute formaldehyde solution. The sprinkling method as perfected by him and his contemporaries was adopted generally by American plant pathologists and is, at the present time, the common method of oat seed disinfection. In spite of the fact that it is one of the easiest, cheapest, and most efficient methods of plant disease control, it is not as widely employed as it should be, even with the great amount of publicity that has been given it. The wetting of the seed is objectionable to many.

Bolley[2] recognizes that a dry formaldehyde treatment would prove more popular with farmers and made some tests with this idea in mind. He obtained very encouraging results but has not yet proposed a method that can be put into practice on a large scale. Clinton[3] performed an experiment in the laboratory which indicated strongly that formaldehyde can be employed as a vapor in disinfecting oats to prevent smut, but nothing further seems to have been done by him looking to the elimination of the great volume of water called for in the original formula. Wheeler's work[4] with the influence of formaldehyde vapor on wheat seed and stinking smut also indicates the possibilities of this substanceas a smut preventive. Arthur's[5] rapid method of spraying falling grain in elevators with a 25 per cent formaldehyde solution is in reality a wet process rather than a dry one.

In view of the desirability of a dry treatment the writer has conducted

[1] Bolley, H. L. New studies upon the smuts of wheat, oats and barley. North Dakota Agr. Exp. Sta. Bul. 27: 109–162. 1897.

[2] Bolley, H. L. The prevention of smuts of cereal grains and prevention of potato scab. North Dakota Agr. Exp. Sta. Bul. 37: 363–379. 1899.

[3] Clinton, G. P. The smuts of Illinois agricultural plants. Illinois Agr. Exp. Sta. Bul. 57: 289–350. 1900.

[4] Wheeler, W. A. Preliminary experiments with vapor treatments for the prevention of the stinking smut of wheat. South Dakota Agr. Exp. Sta. Bul. 89: 1–19. 1904.

[5] Arthur, J. C. Rapid method of removing smut from seed oats. Indiana Agr. Exp. Sta. Bul. 103: 257–264. 1905.

laboratory and field experiments covering a period of four years, with the use of concentrated solutions of formaldehyde.

As a result of the investigation it has been found when one pint of undiluted 40 per cent formaldehyde solution is well distributed through fifty bushels of viable oats seed, which are then covered for five hours, that the germination of the oats is not impaired and the smut disease is controlled.

The amount of formaldehyde gas given off in evaporation is great enough to penetrate through the pile and to destroy all smut spores. On the other hand, the small amount of concentrated solution applied as a spray is insufficient in quantity to wet the seed to such an extent as to permit any absorption and consequent injury. In fact it often happens that seed thus treated germinate quicker and more vigorously than those remaining untreated. This may indicate that the formaldehyde vapor has a stimulating influence on germination comparable to that resulting from etherization, or there is a possibility that the phenomenon may be explained by the fact that the treatment frees the seed from certain semiparasitic and injurious organisms that may be associated with it.

When this method was first put into practice it was found that one pint of formaldehyde solution was hardly sufficient to satisfactorily cover fifty bushels of oats. Subsequent tests brought out the fact that the commercial 40 per cent solution could be diluted with water to one-half strength and then applied at the rate of one quart to fifty bushels of seed with better results.

The method as revised and as at present recommended may be briefly outlined as follows: As the seed is being shoveled from one pile to another each shovelful is sprayed with a solution consisting of one part of 40 per cent liquor of formaldehyde and one part of water. This solution is used at the rate of one quart to fifty bushels of seed. A small quart sprayer is a convenient one to use for the purpose. After the oats are all treated in this way they are piled in a heap and covered with blankets, canvas, or sacks to confine the vapor. At the end of five hours the seed may be uncovered and planted. As formaldehyde vapor acts as an irritant to the mucous membrane of the eyes, nose, and throat, the sprayer should be held down close to the pile and a circulation of air should be provided.

The conclusions stated above as to the effectiveness of this method are based on three personally conducted field experiments in two different seasons, and nineteen cooperative experiments, all of which were accompanied by germination tests for seed viability. In addition to this, to insure that there need be no hesitation whatever in recommending the treatment to farmers, it should be stated that numerous favorable testimonials have been received from those who have tried the method.

The field experiments were carefully checked, there being in one case a control for every two trial plots. All precautions were taken to avoid recontamination of the seed after treatment. These precautions included the use of clean containers, disinfection of the drill, and a consideration of the order of planting the different lots of grain. In all germination tests from one to two hundred seeds were used, and in recording the percentage of smut two or three thousand panicles were counted in different parts of each plot. The amount of smut in some of the checks ran as high as 25 per cent while that in the plots of treated seed was negligible.

In the cooperative experiments the amounts of treated seed varied from two to thirty bushels. In these cases the treatment was supervised or made by farm bureau agents or other competent persons. Treated and untreated seed were in all cases sent to the writer and tested by him for germination in the laboratory. Suitable checks were left in all cooperative fields and the percentage of smut in them determined in most instances by the cooperators themselves. Some of them reported as high as 25 per cent smutted heads with practical freedom from smut in treated plots.

The chief advantage of the dry method over that in which the 40 per cent solution of formaldehyde is sprinkled at the rate of one pint to forty gallons of water lies in the fact that the seed is not wet. This makes it possible to drill immediately after the disinfection is completed, a very important item when weather conditions are considered. The oats do not swell nor do they cause trouble by sticking in the drill. The operation is simpler than that of sprinkling, and the treatment is effective and non-injurious to the seed. Furthermore seed disinfected in this way can be kept several weeks after treatment without danger of deterioration. The method has met with favor in practically all cases where it has been tried.

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REVIEWS

Intoxicating Bread. N. A. Naumov. P'iany Khlieb (Intoxicating Bread). Trudy Biuro po Mik. i Fitopat. No. 12, pp. 1–216, pls. I–VIII, Petrograd, 1916.

A. Pomasski. Ob Izmienen. Khim. Sostava Rzhi pod Vliian. Zhizn. Niekot. Form Fusarium (Chemical Changes in Rye Due to the Activities of Certain Forms of Fusarium). Soobshch. Biuro po Chastn. Rasten. No. 1 (1916), pp. 1–32, Petrograd, 1916.

Considerable attention has been given in recent years by the Russian pathologists to an epiphytotic of cereals, known locally as drunk bread or intoxicating bread, ascribed to certain species of Fusarium. It affects rye, wheat, barley and oats, the maximum infection observed being 88 per cent on barley in 1912. The general appearance of the affected cereals in the field is practically identical in all varieties, a pale green color when young, smaller straw and heads, pink to red and orange-red sporodochia, and, in isolated cases, perithecia at the bases of the stems or in the nodes and on the sheaths. The affected grain acquires toxic qualities which are subsequently communicated to the flour and the bread. When these latter are used by men and animals typical symptoms of poisoning result, i.e., headache, general weakness, and frequently nausea and vomiting.

The disease is known both in European and Asiatic Russia, but with respect to its repeatedness, vigor, and proportions the Primorski region of Eastern Siberia appears to be classical.[1] It was recognized there long ago by the Chinese farmers by the surface film on the affected grains, called *mi-chun*. Russian colonization of this region began in 1862, and first mention of the disease by a scientist was made by Palchevski in 1882. Since then a number of persons, including mycologists, pathologists, and physicians have been working on this phenomenon. *F. roseum* almost invariably occurred in cultures made from the diseased cereals, and O. E. Gabrilóvitch in 1906 demonstrated the toxicity of this fungus. Hypodermic injections have been made into frogs with the extract from pure cultures of the Fusarium with the result that the latter died within three to four hours after inoculation. The toxin was supposed to be a nitrogenous glucoside.

Several years ago the Bureau of Mycology and Phytopathology of Pe-

[1] Of the other countries it has been reported in Sweden and France (Prillieux and Delacroix, Maladies des plantes).

trograd determined to make a thorough investigation of this trouble and formulated two distinct problems: (1) myco-pathological, isolation and exhaustive study of the causal organism with possible reference to the control measures, and (2) biochemical, a study of the chemical changes which take place in the affected grains and the isolation of the active toxin.

The first problem was taken by N. A. Naumov, who just recently published a very interesting report on his work. He submits evidence that the phenomenon "drunk bread" may be caused by either of two species of Fusarium, namely, *F. roseum* Link. (also its ascus stage *Gibberella saubinetti* Sacc.) and *F. subulatum* App. & Woll. The chief distinctive feature of the disease outside of chemical and physiological peculiarities, according to the author, is the presence of the mycelium inside of the grain tissues, which can be proven either microscopically or by means of germinating the seed. Red or pink color of the grain and presence of sporodochia or perithecia cannot serve as leading characters, as they sometimes may be absent even when the grain is plainly affected. In the stems grown from the diseased seed the mycelium has been found nesting in the tissues and penetrating the cells and intercellular spaces, but it is absent in the vascular bundles as well as in the primary meristem. No anatomical changes were observed in the infested stems, but the seeds suffer severely, as starch is dissolved and frequently the embryo is mummified. The disease is communicated to the new crops through infected seed or infected soil, or from an adjoining infested field. The germination of ascospores and conidia takes place in neutral, slightly acid or slightly alkaline media, a slight alkalinity being tolerated better than the corresponding acidity. An excess of moisture in cultures favors the growth of mycelium but is unfavorable for the production of conidia. The best media were found to be rye in grains, heads of wheat, heads of rye, and milk. The minimum temperature for germination of conidia is 4°C., optimum 28°C., and maximum 32°C.; for ascospores, 8°C., 30°C., and 32°C. respectively. Optimum growth of mycelium occurs at 30°C.; there is no growth below 3°C. or above 33°C. The best formation of the conidia and perithecia is at 20°C. Change in temperature is more beneficial for fruiting than injurious. Heating of ascospores for twenty-four hours at 65°C. destroys their ability to germinate. The mycelium completely loses its vitality in grains if the latter are stored under ordinary conditions for a period of three years. Heating rye for twenty-four hours (and up to three days) at 66°C. and wheat, oats and barley at 60°C. does not affect the vitality of the seed, but kills the infesting mycelium. This may prove to be the chief method of treatment. Other control measures suggested are, (1) selection of healthy seed, (2) two to four years crop rotation with root

crops and legumes as intermediate crops, (3) threshing at once after harvesting and possibly treatment of the portion intended for seed with 0.5 to 1 per cent copper sulfate to prevent spread of the disease in storage (in this case the seed should be dried before putting in granaries), and (4) general sanitation and disinfection of sacks and implements. Positive results were obtained in artificial inoculations when soil, shoots, and heads were infected with the conidia and the ascospores and when soil and shoots were infected with the mycelium. Considerable attention is given by the author also to the taxonomic side of the problem.

The biochemical part of the problem has been studied by A. Tomasski, and a preliminary paper dealing with this work has been already published. In it the author shows the chemical changes which take place in rye as the result of the activities of *F. roseum* and *F. subulatum*. He finds that these activities lead to a marked loss of dry substances, which decrease to 67.3 per cent in ten days and to 25.1 per cent in two months. This loss takes place chiefly at the expense of starch and proteins. Decrease of starch in one month of decomposition reaches from 61 to 80 per cent and in two months from 86.5 to 89.5 per cent of the original quantity. Decrease of the general amount of nitrogen in two-month's cultures equals 12 to 16 per cent. Both forms of Fusarium affect rye in more or less the same way. Other changes as well as the products of decomposition are to a certain extent determined. A detailed study of these products and, particularly, isolation and study of the toxic substance of "drunk bread" will constitute a subject for the further studies of the author.

MICHAEL SHAPOVALOV

Manual of Fruit Diseases. By Lex R. Hesler and Herbert Hice Whetzel. xx + 462 pp., 126 illustrations. Published by the Macmillan Company, New York, 1917.

The book is one of the publisher's series of Rural Manuals and has been written with the definite aim of giving the fruit grower a working knowledge of fruit diseases. The treatment of the subject is from the field rather than from the laboratory standpoint.

The arrangement is alphabetical by crops, the diseases under each crop being approximately in the order of their economic importance. The fruit crops included are apple, apricot, blackberry, cherry, cranberry, currant, gooseberry, grape, peach, pear, plum, quince, raspberry and strawberry. There is a concise chapter on the preparation and application of fungicides. Diseases common to more than one host are discussed fully under the most important one and listed under others with such special comment as may be warranted.

The discussion of each disease of major importance includes its general history, geographical range with special reference to regional occurrence in the United States, the nature and extent of losses caused, general effects on the host and diagnostic symptoms, relative susceptibilities of host varieties, the cause of the disease with discussion of contributory factors, the life histories of parasites with particular reference to seasonal development and conditions influencing outbreaks, control measures with emphasis on the rational basis for such measures as well as on the practical details of their application. Well selected illustrations give typical gross features of the diseases. Minor diseases are accorded unusually full discussion. Reference lists under each disease direct the reader to the more important readily available publications, mainly American.

Out of consideration for the grower technical details of taxonomy, morphology and histology have been omitted; and the use of technical terms, while not by any means avoided, has been reduced to the bare requirements of concise statement. A glossary gives brief definitions of many of these terms.

The style is not the unfortunate kind that sometimes characterizes the popular treatment of a technical subject. It has the directness, clearness, exactness and suitableness expected from scientists who are also teachers. The book can be read by either layman or specialist without mental fatigue.

Any student of plant pathology will find the book helpful for reference. With the usual laboratory work to supply a proper morphological and histological framework, the only important limitation to its usefulness as a textbook in general plant pathology courses is the restriction of its scope to a particular group of diseases.

A few defects will be apparent to the critical grower or pathologist. These cannot be pointed out in detail in this review; they would require in the main but slight revision for remedying—a shifting of emphasis here and there, a fuller explanation and illustration of certain technicalities, the correction of occasional lapses from the usual excellence of treatment, the addition at times of another desirable reference, the inclusion as synonyms of imperfect stage names of fungi that have been known commonly by such names, the amplification or modification of details in certain control procedures, the giving with greater reserve of recommendations for control by dusting with sulphur, a broadening geographically of the intimate statements about orchard conditions Attention may be called to differences in the usage of common names from the provisional list prepared by the committee of the American Phytopathological Society. For apple, apricot and blackberry, thirty of the diseases listed by the committee are treated in the Manual; twelve of these are under preferred common names different from the committee's recommendations; and in

ten cases out of the twelve the committee's names do not appear in the unusually complete index.

The volume is a distinctly helpful advance in the somewhat slow evolution of a book literature of American plant pathology.

H. R. FULTON

PHYTOPATHOLOGICAL NOTES

Method for photographing culture plates. A most satisfactory method of making photographic reproductions of bacterial colonies on culture plates has been found as follows:

The petri dish is placed directly upon the sensitive side of the photographic paper and the cover of the dish removed. The culture plate is

FIG. 1. DIRECT PRINT OF BACTERIAL COLONIES

then exposed directly beneath a light for a few seconds and the print developed. The writer uses Azo, glossy Hard C, and a frosted Mazda 40-watt light with exposure made on a shelf about twelve inches below the light.

The advantages of this method are plainly to be seen. First, no negatives are required; second, the process is rapid and many prints can be made in a very short time; third, considerable expense in materials and the operator's time is saved and uniform results are obtained. Also a saving of valuable filing space, occupied by photographic plates that are not always satisfactory, is accomplished. W. S. FIELDS

Methods for the differentiation of pathogenic fungi in the tissues of the host. In the investigation of problems in plant pathology it is frequently desirable to be able to locate and trace the mycelium of a pathogenic fungus in sections of the tissues of the host plant. To this end recourse is usually had to some method of staining by which the hyphae may be differentiated from the cells of the host. For this purpose several special stains and methods have been devised, notable among which are Durand's[1] and "Pianeze III b," as described by Vaughn.[2] It is said that these stains, while producing excellent differential effects with some material, can not always be depended upon to define sharply all mycelium regardless of species and fungus and host.

The writer has been fortunate in the application of two methods which, so far as he is able to determine, have not been described heretofore in this connection.[3] These methods are stated here in the hope that they may be effective when others fail to give the desired results.

The first method consists of a methylene blue-clove oil-eosin combination[4] applied to paraffin or free-hand sections as follows:

Having dehydrated the sections in absolute alcohol, stain 3 to 30 minutes, or longer, in a filtered, saturated solution of methylene blue in absolute alcohol; rinse off excess of stain in water; dehydrate rapidly by flooding inclined slide with a few drops of absolute alcohol; drain immediately and flood sections with a few drops of a filtered saturated solution of eosin or erythrosin in clove oil; watch extraction of methylene blue and taking of counterstain with microscope until desired effect is produced (which should be in from 1 to 10 minutes); flood inclined slide with a mixture of equal parts of absolute alcohol and xylol to remove excess of clove oil stain and prevent formation of an objectionable red precipitate, and place in xylol to clear.

This method, judiciously followed, produces a deep blue stain in the protoplasm of the fungus and a lighter blue in the protoplasm of the host cells, while the cellulose cell walls of the host take a deep pink or red, as well as the walls of the hyphae. Hence, if a piece of mycelium traverses or lies in a cellulose host cell wall, its course is shown by the blue stain

[1] Durand, E. J. The differential staining of intercellular mycelium. Phytopath. **1**: 129–130. 1911.

[2] Vaughn, R. E. A method for the differential staining of fungous and host cells. Ann. Missouri Bot. Gard. **1**: 241–242. 1914.

[3] Dr. Neil E. Stevens and Dr. Lon A. Hawkins have been kind enough to mention the first of these methods in the Jour. of Agr. Research **6**: 362, and 635 (footnote), 1916, respectively.

[4] Zimmerman, A. Botanical Microtechnique (Translated by Humphrey, 1893). On p. 185 the use of eosin in clove oil as a counter stain in Gram's gentian violet method is mentioned.

of its protoplasmic contents, while if it passes through protoplasm of the host, its path is marked by the pink-stained walls of the hypha and its frequently more dense protoplasm. The presence of fungi in lignified elements of the host is shown by the pink hyphal walls against the blue background of the lignified walls.

It has been found that the methylene blue sometimes washes out too easily from the protoplasm of the fungus. Mordanting the sections in an aqueous solution of tannic acid (about 10 per cent) for half an hour, washing in water, and dehydrating to absolute alcohol before applying the methylene blue has proved to be of considerable advantage in holding the stain in the protoplasm of the fungus.

The second method, anilin water, safranin and clove oil—lichtgrün[5] may be described as follows: Stain sections 1 to 12 hours in anilin water safranin;[6] rinse in water; dehydrate by giving slide a quick dip into each of 70 per cent, 95 per cent and absolute alcohol; flood sections immediately with a few drops of a filtered, saturated solution of lichtgrün in clove oil (twice rectified); proceed as for first method.

The differentiation of the fungus in this case depends upon the deep red stain of its protoplasmic contents against a light green in the cellulose cell walls of the host or the light green hyphal walls against the pink or red protoplasm or lignified cell walls of the host.

The secret of success with these stains seems to lie in retaining as much as possible of the first stain in the protoplasm of the fungus before the application of the clove oil stain. This latter extracts the first stain in a differential manner and at the same time has a counter-staining effect, hence the necessity of carefully watching the first few slides of a series from a lot of material in order to determine the time required for each operation. While slides stained by these methods have been prepared for over a year and still show good differentiation, the stains will doubtless fade in time and therefore may not be desirable where it is planned to preserve the preparations indefinitely. The advantages of the methods lie in the facts that, in certain cases at least, they produce excellent differentiation, that they are easy to apply, and that they are relatively simple and inexpensive in composition.

Both of these methods have been found effective in connection with

[5] This stain was first brought to the writer's attention by Mr. E. G. Artzberger of the Office of Agricultural Technology, Bureau of Plant Industry, who was using safranin and an aqueous solution of lichtgrün with partial success for the differentiation of fungi in host plant tissues. Following a demonstration of the clove oil method he promptly discarded the aqueous solution method in favor of the one herein described.

[6] General Formula. Chamberlain, C. J. Methods in Plant Histology, second edition, 1905, p. 38.

Botrytis (cinerea?) and *Rhizopus (nigricans?)* in strawberry fruits,[7] *Pythium debaryanum* in Irish potato tubers,[8] *Fusarium* sp. in tobacco stems, the aecial stage of crown rust of oats in leaves of *Rhamnus cathartica*, and several unidentified organisms in the roots of various plants.

CHARLES S. RIDGWAY

Development of blister rust aecia on white pines after they had been cut down. A small plantation of badly diseased pines set out for seven years at Cookstown, Ontario, was cut down between November 9 and 15, 1916. The trees, many of which were two to three inches in diameter were left lying on the ground or more or less loosely piled until the spring of 1917. On May 10, 1917, the field man assigned to this district reported that fresh aecia were appearing around the old blister areas in these pines, which had not meanwhile been disturbed. A visit was at once made, which confirmed his observations. Where the trunks still retained some moisture new aecia were pushing out around the old blister areas. They were apparently as numerous as usual, though rather smaller than normal in size. In the drier stems, aecial development had occurred under the bark, where spores were being produced in immense numbers in irregular masses, forming an almost complete layer for 6 inches or more beneath the bark. This layer-like mass of spores extended under the old infections as well as beneath the bark of adjacent tissue, which had up to this time borne no blisters. Since about 25 per cent of the stem cankers were thus producing their usual crop of blister spores in this case, the menace that may arise from pines not completely destroyed, is clearly apparent.

During the course of field observations upon an area of diseased pines at Kittery Point, Maine, trees eight to thirty-five years old with basal diameters 2 to 8 inches were cut down in November and December, 1916. Many cankers were collected for exhibition material and the remaining slash left on the ground over winter. On May 2, 1917, mature blisters were found on stems and branches of various sizes which were cut November 18. Subsequent observations showed that aeciospores were produced on approximately 60 per cent of the infected stems and branches Normal blisters were formed in many instances, and in several cases where the cut ends of stems were placed in running water spore production continued until June 18. On infected stems 3 to 8 inches in diameter which began to dry out before blisters showed through the bark, spores were produced in irregular masses under the hardened bark. Some of these

[7] Stevens, Neil E. loc. cit.
[8] Hawkins, Lon A. loc. cit.

spore masses retained normal color until June 25, after which the orange color was lost and the spores appeared in light grayish masses when the bark covering was removed. On June 3, 1917, a sporulating canker on a limb 2 inches in diameter which had remained on the ground since November was sent to Washington. Germination tests made of the spores at Washington, June 6, gave positive results. Spores from this canker were used for inoculating a plant of *Ribes nigrum* under greenhouse conditions on June 8, and normal uredinia were subsequently produced. On March 20, 1917, freshly cut infected branches and one section of a stem 4.5 inches in diameter were received at Washington. The branches were set in water and blisters appeared in a few days. The stem section was about three feet long. All side branches were closely trimmed off and it was set on top a case near the ceiling of the laboratory. About May 1 blisters were pushing through the bark in spite of the drying effect of the heat.

These findings show that wherever diseased pines are removed the brush and affected parts of the trunks must be carefully collected and burned in order to make the work effective.

W. A. MCCUBBIN AND G. G. POSEY

Control of lettuce rot. A soft rot of lettuce of the type described by Miss Brown[1] and ascribed to *Bacterium viridilividum*, has been seen in many fields in Michigan doing enormous damage to the crop. What appears to be the same disease has been found in the market at Chicago in lettuce from New York as well as from other states. Carload after carload of lettuce arrives in the great markets almost a total loss. Fifty per cent loss is not uncommon in the field, and this, coupled with the loss which occurs in transit, makes the growing of head lettuce in some seasons very precarious.

The disease starts first at the tips of the leaves, probably in the dead areas which come at the edges of the older leaves. These areas shrivel and curl and are marked off from the healthy tissue by a definite line. With the inner leaves the rot progresses very deep into the head, turning their tender leaves into a gluey slime. The deep involvement of the inner leaves and the comparatively small amount of rot of the outer leaves is characterisic of the early stages of this trouble. Eventually the whole head rots.

The purpose of this note is to call attention to the remarkable control of the disease obtained by spraying diseased plants with formaldehyde, 1

[1] Brown, Nellie A. A bacterial disease of lettuce. Jour. Agr. Research **4**: 475–478. 1915.

pint to 30 gallons of water. In tests in 1916, at Bay Port, Michigan, the disease was checked by this treatment in fields which were about to be given up as a total loss. The weather had, however, become very cool, hence the relation of the formaldehyde spray was not definitely proved.

The present season the rot began to be serious during an extremely wet and cold period in July. Spraying with formaldehyde has completely checked the trouble. In an adjoining field, the owner, seeing the success of the formaldehyde treatment, sprayed a portion of his field. In the sprayed portion the disease is checked while the unsprayed field shows a high percentage of rotting. A third field in the neighborhood, unsprayed, is almost a total loss.

Attention is called to this control measure because the results of the trials during two seasons warrant extensive tests of treatment. It may be pointed out that we have here a method which differs from the ordinary protective spray, in that it seems actually to check disease already in progress. It is believed that this treatment will be found to have a wide range of adaptability in the treatment of diseases of this type.

EZRA LEVIN

LITERATURE ON PLANT DISEASES

COMPILED BY EUNICE R. OBERLY, LIBRARIAN, BUREAU OF PLANT INDUSTRY, AND FLORENCE P. SMITH, ASSISTANT

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